POWER PLANT ENGINEERING

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Heat Saving Number

Page

Hold the Heat and Make It Do Your Work..... 2
Progress in power generation is definitely indicated by decrease in coal consumption per kilowatt-hour. Better equipment, more thorough knowledge and vigilant operation are reaping the harvest by saving heat.

Sources of Heat for Power Generation..... 4
Fuels may be raw, natural materials, prepared or modified products of industrial processes or materials rejected by a factory.

Some Combustion Losses Cannot Be Eliminated..... 6
They can often be decreased materially, however, by proper air supply, reduction of air infiltration and use of preheated combustion air, all these factors being to some extent under the control of the operator.

Careful Operation Reduces Avoidable Losses..... 7
Analysis of losses due to combustible in refuse and in stack gases.

Furnace Heat Is Used in Three Ways..... 8
Heat left after losses are subtracted is used for heating water, making steam and in radiation losses.

Where the Steam Energy Goes..... 9
Some of it is dissipated by radiation and leakage; most of it is used in prime movers, in heating water and buildings and in process work.

Evaporation, Deaeration and Heating..... 11
Heat used for these purposes can be saved by care in operation, efficient equipment and good insulation.

Conversion of Heat Into Work..... 13
Discussion of principle of conservation of energy, friction in bearings, heating of generators and the changing of heat into useful work.

Proper Fuel Necessary for High Efficiency..... 15
To obtain best results, physical as well as chemical properties of fuel must be considered in relation to furnace and grate.

Firing Method Must Suit Coal and Equipment..... 16
Details of methods that prevent heat losses with hand firing, underfeed and overfeed stokers and traveling grates.

Saving Heat in Pulverized Coal Firing..... 20
Preventing loss of coal, use of proper burners and correct proportions of fuel and air.

Proper Air Supply Promotes Good Combustion..... 21
Details of various types of fans and control methods used to supply correct amount of combustion air in the right place at the right temperature and pressure.

Improving Efficiency of Combustion..... 27
Discussion of requirements for good combustion, reduction of losses by control of air supply, CO_2 measurements, use of pyrometers.

Stopping Heat Loss Through Boiler Walls..... 29
Analysis of losses through solid, air-cooled and water-cooled walls and details of methods for preventing these losses.

Heat Loss from Other Parts of Boilers and Settings..... 31

Furnace Bottoms..... 32

Clean Surfaces Are Best for Heat Transfer..... 33
Modes of heat transfer, portions of boilers designed to absorb heat, methods of keeping surfaces clean with soot blowers, tube cleaners by deconcentrating and blowing down.

Feedwater Treatment..... 38
Discussion of some of the common impurities found in feedwater and general types of water treatment.

Effect of Water Circulation in Boilers..... 39

Importance of Baffling in Securing Economy..... 40
Tight, well-built baffles prevent short-circuiting of gases and permit highest possible efficiency. Analysis of heat loss in gas leaving boiler.

Reclaiming Heat from Flue Gases..... 42
Types of air preheaters and economizers and heat saving due to their use.

Economical Use of Heat in Steam. By Frank O. Ellenwood..... 45
Precautions must be taken to prevent radiation and leakage and to convert as much as possible of the heat energy in steam into useful work. In this endeavor, important factors are piping, prime mover design, feedwater and other heating, high superheat, good condenser practice.

Saving Heat in Steam Piping Systems..... 47
Determination of economical thickness of insulation, drainage of condensate, importance of dry steam.

Efficient Prime Movers Conserve Heat..... 49
High steam pressures and temperatures, extraction feedwater heating and good loading are factors to be considered.

Utilizing Heat of Exhaust Steam..... 52
This can be done with building heating systems and with several types of feedwater heaters, besides using exhaust steam in processes.

Condenser Operation and Use of Condensate..... 54
Heat is saved by using condensate as feedwater and by using condenser cooling water after it has done its work in the condenser.

Saving Heat in Evaporator Systems..... 56
Evaporators help in reducing boiler cleaning and in increasing heat transfer.

Deaerators Reduce Corrosion..... 58

Reducing Friction Losses..... 59
Detailed discussion of alinement, upkeep and lubrication of bearings, of belting and of friction in gearing and chain drives.

Economies in the Utilization of Power.
By Edward H. Waldo..... 62
To save the high-value electrical energy, distribution equipment should be studied and losses in power-using apparatus analyzed.

Analysis of Losses in Electric Circuits..... 63
Heating of wiring, operation at efficient loads, power factor correction, generator losses.

Saving Energy in Compressed Air Systems..... 66
Efficient, well-maintained machines with good lubricaiton and tight piping systems reduce losses.

Heat Unit Salvaging in a Diesel Engine System..... 68
Analysis of heat losses in jacket water and exhaust gases and details of methods used to reclaim much of this heat.

Letters Direct from the Plant: Power Demand vs. Brick Machine Operating Conditions. Practical Knowledge for the Asking. Asphyxiated Fires. Construction Change Avoids Valve Breakage..... 71

Questions and Answers: Refrigeration Power Calculation. Bleeder Turbine Regulation. Boiler Blowdown..... 74

Editorial Comment: To Our Friends—A Year of Prosperity. Will Power Plant Pressures Decrease? The Modern Show Boat. Series Synchronous Condensers. Industrial Research. Acknowledgment..... 76

Fiftieth Annual Meeting of A.S.M.E...... 78

International Conference Adopts Skeleton Steam Tables... 83

Eighth National Exposition of Power and Mechanical Engineering..... 84

A.S.M.E. to Celebrate 50th Anniversary in April, 1930..... 93

Fred R. Low Retires from Active Editorial Work..... 93

News Notes..... 93

Books and Catalogs..... 94

Power Plant Construction News..... 96

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FIG. 1. UNCERTAINTY OF FUEL SUPPLY TO THE FURNACE HAS BEEN OVERCOME BY THE AUTOMATIC STOKER; VARIABLE OPERATING CONDITIONS ARE DEFINITELY REVEALED BY INSTRUMENTS. SUCH EQUIPMENT IS ESSENTIAL IN HEAT SAVING PROGRAM.

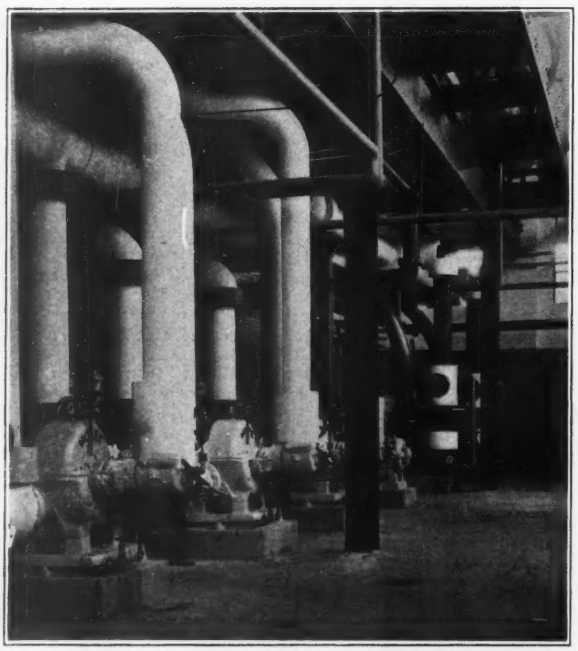


FIG. 2. GOOD INSULATION IS, AS IT SHOULD BE, A CONSPICUOUS FEATURE OF ECONOMICAL STEAM PLANTS.

Hold the Heat

TEN YEARS AGO, the amount of power generated per pound of coal burned in public utility power plants was 0.312 kw-hr. In 1928 this power had increased to 0.57 kw-hr. This means that for every pound of coal burned in this way, the industry now converts 539 B.t.u. more into electric energy than it did ten years ago. When the yearly coal consumption in the United States is considered, the heat saving effected by advanced practice runs up into astounding figures.

Unquestionably the better class of equipment now installed in power plants is responsible for a large percentage of the saving effected. The bulk of the saving, however, must be accredited to a better understanding of the processes that take place in the power plant. This knowledge has brought about the growing use of heat saving equipment and the development of instruments that keep the attendants informed as to immediate conditions.

Each plant, of course, has its individual characteristic problems ranging from the selection of the most economical fuel to the utilization of the power and heat generated, so the problem of heat saving involves making a survey of plant equipment and operation to determine the results being secured. Comparisons can then be made with results secured in other plants to determine whether or not heat, in its various forms, is being needlessly wasted.

To save time in getting at the principal losses, it is well to start with a determination of overall operating efficiencies of the principal equipment in the plant—boilers, prime movers, pumps, heaters, exciters—then, when it has been determined where the greatest preventable monetary loss occurs, a detailed study of all conditions surrounding the operation of the equipment should be made. In cases involving a steam cycle, a heat balance chart should be made up, listing the various items as determined by test and against these should be listed the values that should be expected from equipment similar to that under investigation.

In arriving at the losses, the equipment should be tested under the most ideal conditions possible in order to obtain an ideal for which to aim in the operation of the plant. When, in operation, any of these losses increases unduly, the causes should be determined and the conditions corrected immediately.

In the following pages, the principles underlying the efficient combustion of fuel, the absorption of heat and its conversion into power are discussed with emphasis laid upon conditions that cause the diversion of heat units into uncontrolled paths and how these conditions can be corrected. In converting the heat in coal into electric energy, scarcely 10 per cent of the original heat reaches the desired destination. It will be noted, there-

and Make It Do Your Work

Progress in Power Generation is Definitely Indicated by Decrease in Coal Consumption Per Kilowatt-Hour. Better Equipment, More Thorough Knowledge and Vigilant Operation Are Reaping the Harvest by Saving Heat.

fore, that a loss of one heat unit in the electric transmission line is equivalent to 10 or more units lost from the fuel. In other words, the value of a heat unit increases with each conversion in the direction toward the final product. With this in mind, the economic value of stopping heat waste at any stage in the transition can readily be calculated from the cost records of the plant.

Fortunately the engineer has a standard by which he can judge the degree of perfection of his results. When he reaches 100 per cent efficiency in any conversion, he can do no better, i.e., when the energy output equals the energy input. No sane engineer, however, expects to attain that degree of perfection and certain transitions are far from perfect in the best plants. Below is given a list of losses approximately as they occur in an average fairly well operated plant:

1 lb. Coal average	13,500 B.t.u.	
1 lb. Coal (13,500 × 778) ÷ (60 × 33,000)	5.3 hp-hr.	
Lost through grates	1.00	per cent.
" boiler radiation	5.00	" "
" chimney gases	22.00	" "
" main pipes radiation	1.56	" "
" auxiliary pipes radiation	.22	" "
" auxiliary exhaust	1.40	" "
" engine radiation	2.08	" "
" engine exhaust	57.31	" "
Total loss	90.57	" "
Converted to power	9.43	" "
Total heat of coal	100.00	" "

Each year improvements are being made and the losses enumerated are being reduced. The item of boiler radiation given here as 5 per cent loss is being reduced in many plants by the use of water and air-cooled furnace walls. The use of economizers and air preheaters is reducing the 22 per cent chimney losses to a relatively small fraction of that amount. Engine exhaust given as 57.31 per cent is being reclaimed to a great extent by use in processes.

To take advantage of present day knowledge of power plant operation will, in many plants, mean an expenditure of considerable capital for instruments that will point to wasteful conditions otherwise unknown, for expert advice and services of engineers to make tests and complete a survey of plant losses, and for new equipment found essential to rehabilitate the plant and bring it up to modern efficiency.

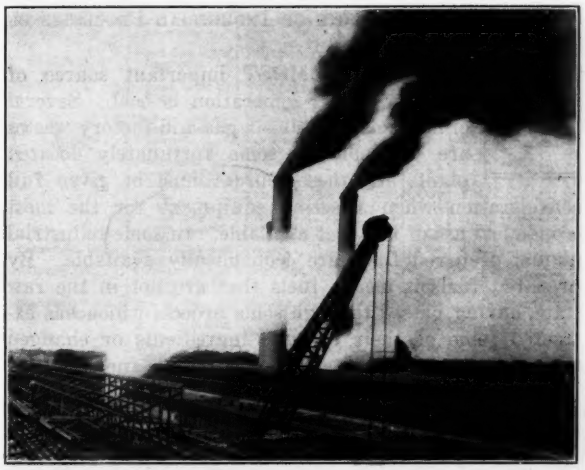


FIG. 3. SMOKING CHIMNEYS AND ESCAPING STEAM ARE FLAGRANT EXAMPLES OF HEAT WASTING

FIG. 4. HEAT HAS A HARD TIME GETTING THROUGH THIS SLAG, SO IT GOES UP THE CHIMNEY INSTEAD

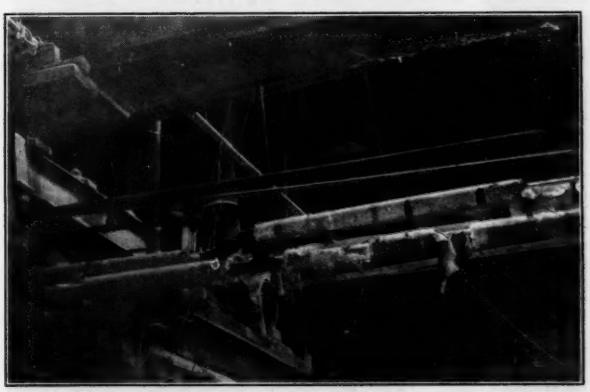


FIG. 5. ANOTHER INSTANCE WHERE THE DEFENSES HAVE GIVEN WAY TO CONSTANT HAMMERING OF THE HEAT UNITS IN THEIR BATTLE FOR FREEDOM

Sources of Heat for Power Generation

FUELS MAY BE RAW NATURAL MATERIALS, PREPARED OR MODIFIED PRODUCTS OF INDUSTRIAL PROCESSES OR MATERIALS REJECTED BY A FACTORY

BY FAR THE MOST important source of heat for power generation is coal. Several other fuels such as oil, gas and factory wastes are available in some fortunately located plants and these sources must be given full consideration when selecting equipment for the most economical use of the heat available. In some industrial plants, prepared fuels are economically available. By prepared fuels is meant fuels that are not in the raw state, having passed through some process which has extracted some of their original ingredients or changed their characteristics quite markedly. Such fuels as coke,

FIG. 1. IN THE VAST MAJORITY OF POWER PLANTS COAL PILES SUCH AS THIS ONE TRANSFER THE CUSTODY OF THEIR HEAT ENERGY TO MEN

petroleum carbon, blast furnace gas, producer gas and colloidal fuel would come under this class.

Another source of heat for the generation of power, available in some industries, is hot waste gases. These have been used economically in cement mills, also in steel mills and coke plants that employ inert gases for quenching purposes. Then again there are rare cases where the heat from volcanic steam or geysers is used in the generation of steam for power purposes. The most extensive use of this source has been in Italy though plants have been developed in some parts of California.

Since consideration is being given here to the sources of heat, mention should be made of the increasing use of electricity for the generation of steam. This arrangement is employed in some industrial plants where steam is required for process work and power is purchased at a low rate, usually from a hydroelectric plant. Since power is already available, the steam thus generated is not used for power purposes.

In the generation of steam from heat derived from any of these sources, it must be remembered that each type of fuel has characteristics which require the maintenance of specific conditions and thus furnace and boiler equipment must be chosen with due regard to the fuel available.

CAUSES OF FUEL LOSS

Responsibility for conducting the heat units from their entrance into the plant to their exit as useful power or heat lies with the engineer. Fuel lost before it enters the furnace seldom receives due consideration. Coal does deteriorate to some extent while in storage and spontaneous combustion is at times the cause of considerable loss. The heat loss due to deterioration of coal in storage varies considerably with different classes of coals. Anthracite may be stored for an indefinite time without an appreciable loss in heat value while tests on Illinois coal show that nut sizes may deteriorate 3 to 3½ per cent and screenings over 5 per cent in one year in outside storage. The accompanying table gives the results of tests made by the U. S. Bureau of Mines on various coals.

Coal intended for storage should be selected, to some extent, with regard to its storage qualities. Coal is stored as a reserve to be used in emergencies to prevent monetary losses due to a forced shutdown of the plant

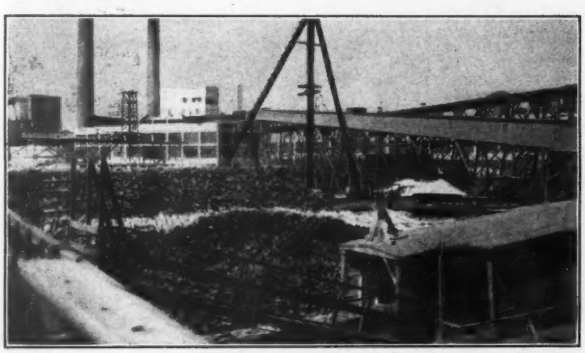


FIG. 2. CORD WOOD FINDS APPLICATION AS FUEL IN THE NORTHWEST

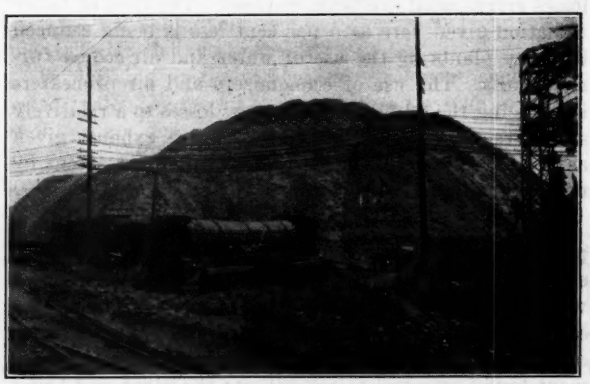


FIG. 3. IN LUMBERING DISTRICTS WOOD REFUSE IS A WINNING COMPETITOR IN THE FUEL RACE

and as a rule a definite amount is kept in storage. Under these circumstances, since deterioration takes place most rapidly during the first few months the coal is in storage, the economical plan is to establish a storage pile sufficient for emergency purposes and in it put coal selected for its storage qualities as well as its adaptability to the furnace. Coal used in the daily operation of the plant, with this arrangement, would not go to the storage pile but would be conveyed from the delivery yard to the plant bunkers in so short a time that no deterioration would take place and a lower grade of coal could be used in regular operation than for storage purposes.

As a precaution against spontaneous combustion, coal in storage must be watched carefully, particularly for the first few months, to detect and prevent excessively high temperatures. The following directions for detecting overheated coal spots are offered:

1. Watch for evidences of steaming in the pile.
2. Note the odor given off; bituminous or sulphurous odors are evidence of heating.
3. Note places where snow on a pile has melted.

APPROXIMATE HEATING VALUES OF DIFFERENT FUELS AS RECEIVED

Fuel	Heating Values B.t.u. per pound
Coal	
Anthracite	13,300
Semi-anthracite	13,150
Semi-bituminous	14,100
Bituminous	13,900
Sub-bituminous	9375
Lignite	7100
Peat	3600
Wood (Air Dried)	
Ash	1420
Beech	1300
Birch	1190
Cherry	1260
Chestnut	940
Elm	940
Hemlock	580
Hickory	1800
Maple, hard	1340
Oak, live	1560
Oak, white	1540
Oak, red	1340
Pine, white	970
Pine, yellow	1050
Poplar	1050
Spruce	970
Walnut	1340
Willow	970
Coke	12,000
Bagasse (dry)	8300
Bagasse (as fired)	4000
Tanbark (dry)	9500
Tanbark (with 65 per cent moisture)	3320
Colloidal fuel	16,670-17,200
Oils	
California	17,117 to 18,875
Texas	18,662 to 20,152
Ohio	19,580
Pennsylvania	19,210
West Virginia	21,240
Mexico	18,840
Gas—B.t.u. per cu. ft., high (gross) 60 deg. F., 30 in. Hg., Satd. H_2O	
Coal gas	634
Coke oven	536-600
Blue water	310
Carbureted water gas	578
Oil gas	516
Producer gas	136
Blast furnace	93
Natural gas	1047-2469

TABLE GIVING THE HEAT LOSS IN CALORIES OF COALS FROM DIFFERENT DISTRICTS DUE TO STORAGE

Kind of coal.	Storage conditions.	Place.	Calorific value. As stored.	After 3 months.	After 1 year.	After 2 years.	Per centage of loss in 2 years.
New River, W.Va.[a]	½-inch coal, under sea water.	Portsmouth, N. H.	8,761	.....	8,759	8,730	[b] 0.39
		Norfolk, Va.	8,754	.....	8,763	8,737	[b] .49
		Key West, Fla.	8,747	.....	8,752	8,770	0
	½-inch coal, under fresh water.	Pittsburgh, Pa.	8,752	8,762	8,749	8,760	0
	½-inch coal, exposed to air indoors.	Portsmouth, N. H.	8,779	8,738	8,742	8,709	.80
		Norfolk, Va.	8,751	8,743	8,736	8,717	.39
		Key West, Fla.	8,754	8,728	8,676	.....	.....
		Pittsburgh, Pa.	8,769	8,736	8,719	8,720	.56
	R. o. m. coal, exposed to air indoors.	Portsmouth, N. H.	8,754	8,758	8,748	8,734	.23
		Norfolk, Va.	8,743	8,764	8,722	8,725	.21
		Key West, Fla.	8,745	8,733	8,710	.....	.....
		Pittsburgh, Pa.	8,753	8,758	8,740	8,743	.11
	½-inch coal, exposed to air outdoors, uncovered.	Portsmouth, N. H.	8,741	8,730	8,701	8,674	.77
		Norfolk, Va.	8,726	8,709	8,666	8,625	1.16
		Key West, Fla.	8,739	8,721	8,680	8,592	1.85
		Pittsburgh, Pa.	8,763	8,726	8,700	8,665	1.12
	R. o. m. coal, exposed to air outdoors, uncovered.	Portsmouth, N. H.	8,775	8,766	8,760	8,722	.60
		Norfolk, Va.	8,743	8,745	8,720	8,695	.55
		Key West, Fla.	8,752	8,708	8,722	8,632	1.29
		Pittsburgh, Pa.	8,752	8,740	8,716	8,696	.64
Pocahontas, Va.	120-ton pile, r. o. m. coal, outdoors.	Panama	8,794	8,787	8,762	.....	.....
Pittsburg bed	4 tons r. o. m. coal in open bin, outdoors.	Ann Arbor, Mich.	8,541	[c] 8,539	8,526	.....	.....
			8,541	[d] 8,553	8,528	.....	.....
Sheridan, Wyo., subbituminous.[e]	R. o. m., open bin 5 ft. deep.	Sheridan, Wyo.	7,370	7,174	.....	7,135	[f] 3.19
	R. o. m., closed bin 5 ft. deep.	do	7,370	7,202	.....	7,094	[f] 3.75
	R. o. m., closed bin 15 ft. deep.	do	7,370	7,303	.....	6,982	[f] 5.26
	Slack, closed bin 15 ft. deep.	do	7,355	7,166	.....	6,990	[f] 4.96

[a] Heating value of representative mine sample of coal (ash, moisture, and sulphur free), 8,788 calories.
[b] On basis of original heating value of same test portion.
[c] After six months' storage, entire lot in bin.
[d] After six months' storage, upper 6 inches at surface of bin.
[e] Each bin contained 5 to 10 tons.
[f] After two years and three-quarters.

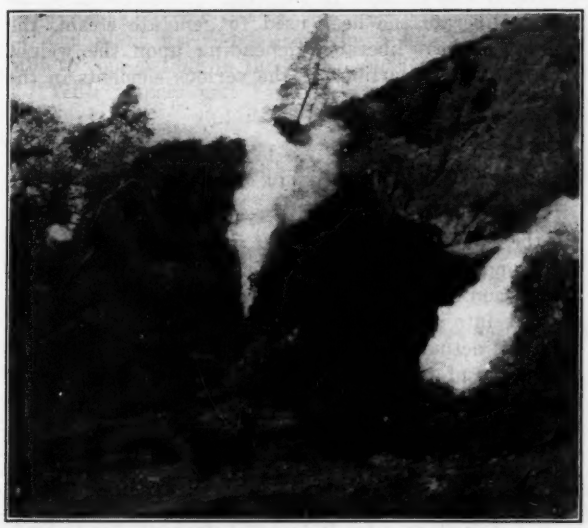


FIG. 4. STEAM WELLS IN CALIFORNIA OFFER POSSIBILITIES FOR GENERATING POWER

4. Insert an iron rod in the pile and note its temperature with the hand after removal.

5. Insert thermometers or thermocouples in the pile.

Again, coal exposed to the weather may accumulate moisture that must be dried out before it can be prepared for pulverizing or cause an additional loss of heat when burned in the furnace. Coal dropped in transit from the storage pile to the furnace is seldom lost as the scatterings are gathered up from time to time. Many plants, however, receive their coal direct from the yards of the dealer, the coal being weighed on the scales at the yard and any droppings between the yard and the plant must be paid for by the power plant. Overloading of trucks and careless driving may be responsible for considerable loss in fuel and an occasional checkup may pay well for the trouble.

Actual loss of gas or oil in power plants is usually negligible as both these fuels are handled in piping and leaks are generally evident.

Where steam is generated by means of waste heat from metal furnaces or other processes, careful heat insulation of the conveying ducts is an essential provision as the radiation loss here may run up to a considerable percentage of the heat available.

In all cases, the fuel should be kept in the best possible condition from the time it comes to the plant until it is delivered to the furnace and actual loss of fuel in any appreciable percentage is inexcusable.

Some Combustion Losses Cannot Be Eliminated

Proper Air Supply, Air Infiltration and Preheated Air Are Factors Which Operator Can Control for the Purpose of Decreasing Losses

IN ORDER TO BURN fuel successfully and utilize the heat liberated to the best advantage, the process of combustion must be analyzed and higher efficiencies obtained by making a critical analysis of the losses involved so as to reduce them to the minimum.

Combustion of fuel in a boiler furnace is a complicated process not understood sufficiently well as yet to allow complete agreement among scientists as to the order in which the necessary chemical changes take place. For practical purposes, however, the process is simple, consisting primarily of the oxidation of carbon, hydrogen and sulphur in the fuel. These chemical reactions liberate the heat used to generate steam, the amount of heat liberated depending upon the weight and relative proportions of the various elements in the fuel.

Ultimate Analysis Gives Indication of Heating Value

Heat developed is used in two ways, first in bringing the fuel and air to the point where combustion takes place and second in heating the gases or products of combustion. Heat for the first step is further subdivided into two parts, the sensible heat required to raise the actual temperature of the fuel and air itself, a function of the specific heat of the two, and the heat required to dissociate the hydrocarbons formed into their respective elements so that they are free to combine with the oxygen of the air.

Coal is the most widely used fuel and an ultimate analysis gives the proportion of each element contained in it but it does not tell in what form these elements exist or in what form they are distilled from the fuel during combustion. A certain coal may show in an ultimate analysis, 7 per cent hydrogen and 40 per cent carbon. From this the theoretical heat liberation can be calculated. If most of the hydrogen exists or is distilled off as methane, CH_4, some heat will be absorbed in breaking this down, so that the net heat liberation will be lower than calculated. Losses involved in the combustion process itself are inherent and cannot be eliminated.

Available heat beyond these combustion losses is used in raising the temperature of the gases of combustion. From the gases or incandescent particles of burning fuel, heat is transmitted to the furnace walls and boiler tubes both by radiation and convection. As the gases travel over the heating surface, they give up heat and are gradually cooled, the lower limit of this cooling depending upon the type of boiler and the rate of firing.

With a boiler only, obviously the lowest temperature to which the gases can be cooled is that corresponding to the saturation temperature of the boiler drum. As the pressure is raised, the lower limit of cooling is raised and the losses increased.

Dew Point Limits the Heat That Can Be Reclaimed from Flue Gases

With an economizer, the limiting temperature is lowered to that of the boiler feedwater, while with an air heater of sufficient size the limiting theoretical temperature is that of the surrounding air. Practically, however, the limit of cooling, either with an economizer or air heater, is the dew point of the gases although occasionally without fans the draft must also be considered because the available draft depends upon the temperature difference between the atmosphere and flue gases.

The dew point is the temperature at which moisture in the gas condenses. After condensing sulphur products are absorbed and a corrosive action started by the resulting sulphuric acid. This moisture comes from moisture initially in the coal and air as well as that formed from the combustion of hydrogen. Loss due to this item is equal to the heat required to evaporate the water and superheat it to the temperature of the exit gases. The combustion of hydrogen liberates heat and although the vapor formed is not a loss in the sense that the other vapor losses are, it is troublesome and adds to the danger of corrosion.

There is, then, a flue gas loss with all types of equipment which, although it can be reduced, cannot economically be eliminated. The actual heat loss depends upon three factors: the specific heat of the gas,

the temperature above atmospheric temperature or an arbitrary chosen datum, and the weight of the gas.

Excess Air Causes Losses Which Can Be Reduced

Specific heat depends upon the composition of the gases but is practically constant for all gases found in service, the A. S. M. E. test code using a value of 0.24 for dry gases. Temperature can be controlled by equipment design and if fuel prices are high enough the loss can be reduced to the practical minimum, that is the dew point.

Weight of the gases is the factor over which the greatest control can be exercised by the operator. For the combustion of a certain amount of a given fuel a definite amount of air is required. Because of the short time available for combustion in the furnace, it is difficult to get each molecule of oxygen in the air in contact with the fuel so that an excess amount of air must be supplied in order to avoid losses due to unburned combustible.

Air being only 20 per cent oxygen and 80 per cent of inert nitrogen, an addition of say 20 per cent of excess air means a comparatively large increase in the total weight of exit gas per unit of fuel. This additional amount of air means a heat loss equal to the amount of heat required to raise the excess air from its initial or room temperature to that of the exit gases.

Enriched Air Would Decrease Gas Losses

The CO_2 in the gases is a measure of thoroughness of combustion and considered in relation to the CO and O_2 is a measure of the amount of excess air used. If insufficient excess air is provided, the loss from incomplete combustion will be high. If the excess air is too high the exit gas loss will be high. With each furnace there is a fairly definite point which gives the most efficient operation. This depends largely upon the furnace design, coal and load.

Excess air is sometimes used in a somewhat different way to reduce the temperature of the furnace and avoid high refractory maintenance. This is an illustration of creating one loss to eliminate a larger one. An effective method of reducing losses due to flue gas temperature would be to supply enriched air, that is air having a higher percentage of oxygen than normal. This has been done in certain metallurgical processes and has been considered, if not actually used, for burning low grade coal. Centrifugal equipment, used for the enriching process, depends upon the difference in specific gravity of the oxygen and nitrogen in the air.

Air infiltration through the boiler setting back of the combustion chamber is particularly bad, as this air takes no part in improving combustion but does carry off large quantities of heat. Gas samples should be taken in different parts of the boiler as well as in the breeching to determine where the excess air enters. Naturally, because of the resistance losses through the boiler the draft increases from the furnace toward the breeching so that the tendency toward air infiltration is greatest at the points where it will do the most harm.

Of all methods of decreasing the losses of combustion, the use of preheated air is most effective. It is instrumental in reducing the sensible heat input to the fuel before combustion, cuts down the amount of excess air used and increases the furnace temperature.

One method of preheating air which was used to some extent before the introduction of air heaters and is still applicable to installations where air heaters are not installed, is to use the air for generator cooling for combustion, installations of this kind usually being arranged so that the discharge from the generator enters a plenum chamber from which the forced draft fans take their suction.

Today, however, the common method of preheating air for combustion is, by means of a heater reclaiming heat from the flue gases. The recovery of this heat forms a recirculating heat load through the furnace and boiler and back to the furnace through the heater and air for combustion.

Although heated air for combustion is the greatest factor in reducing losses in the combustion process itself and is the only one over which any degree of control is exercised, the value of low moisture in coal and air must not be overlooked. Neither must the importance of air infiltration through the setting be considered unimportant as losses from this alone may more than overbalance gains from preheating, low moisture and low exit gas temperatures.

Careful Operation Reduces Avoidable Losses

Analysis of Losses Due to Combustible in Refuse and in Stack Gases

FROM THE STANDPOINT of actual operation of the plant itself, however, the greatest loss is that due to combustible in the refuse and in the stack gases.

With stokers and hand firing this loss takes the form of carbon and sensible heat in the refuse and carbon monoxide, CO, in the stack gases. Both are the result of faulty firing although they may result from a variety of causes. Loss of carbon is primarily due to poor firing or stoker operation where fuel is fed too fast and discharged to the ash pit before it is thoroughly burned out or because it becomes cemented in clinkers and unavailable for combustion.

Losses due to combustible in the flue gases are caused primarily by insufficient air or stratification in the furnace preventing the air and gases from mixing. Air supply, of course, also plays an important part in the loss of carbon in the refuse through holes in the fire and faulty control of draft.

Combustion of coal on grates is similar to the action in a gas producer and the gases rising from the fuel bed are rich in carbon monoxide, hydrogen and methane but relatively low in carbon dioxide. That is, all the oxygen in the air is used up in traversing the first few inches in the fuel bed and the CO_2 is at a maximum a short distance from the grates.

From this point combustion takes place through the reduction of CO_2 to CO and the distillation of volatile gases. Changing the draft changes conditions little beyond giving higher rates of combustion. Approximately 7 lb. of air can be forced through a fuel bed without lifting the coal off the grates.

This is approximately half the total amount of air

required for combustion so that the balance must obviously be supplied over the fire instead of through it. Some of the additional air enters through holes in the fire, cracks in the settings, through the lower end of the stoker and through the ash pit. The thoroughness of combustion depends upon the thoroughness with which this air is brought in contact with the rich gases leaving the fuel bed. Furnace design plays an extremely important part in this, both size and shape having an influence.

An interesting difference exists between the flue gas losses in stoker fired and pulverized coal fired furnaces. With grates, losses in the flue gas are confined to CO while, with the latter, flue gas losses are almost entirely in the form of carbon.

These losses, due to incomplete combustion also depend to a certain extent on the type of coal. For instance, it may be necessary to pulverize Pocahontas coal to 75 or 80 per cent through 200 mesh in order to get the same good combustion as would be produced in the same furnace with Illinois coal pulverized 65 per cent through 200 mesh or lignite 40 or 50 per cent through 200 mesh.

For any given percentage of carbon in the refuse, the actual loss in per cent of that fired will increase with increasing ash content and decreasing calorific value. Thus, for a refuse containing 30 per cent carbon, the loss for a 14,000 B.t.u. coal with 4 per cent ash is only about one-quarter the loss for a 10,000 B.t.u. coal with 12 per cent ash.

Furnace Heat Is Used in Three Ways

HEAT LEFT AFTER LOSSES ARE SUBTRACTED USED FOR HEATING WATER, MAKING STEAM AND IN RADIATION LOSSES

AFTER THE LOSSES of combustion have been subtracted from the heat of the fuel, the balance is available for absorption by the boiler heating surface. This available furnace heat is expended primarily in radiation from the furnace walls, heating the boiler water from feedwater temperature to steaming temperature, evaporating the water into steam and, in most plants today, superheating the steam.

It is not practical to separate the stoker, furnace and boiler efficiency so that all losses including radiation are customarily lumped together and the overall efficiency, that is the ratio of the heat absorbed by the steam to the total higher calorific value of the fuel find, considered as the practical measure of performance.

Of course, for purposes of improving efficiency the individual losses must be considered and analyzed so that the contributing causes of low efficiencies can be located. After each loss is investigated in turn and the best operating value, considered not only individually but in relation to other losses, is determined, it is convenient to consider all of these losses as a unit because they can conveniently be determined from simple records of the coal burned and water evaporated.

HIGH COAL PRICE JUSTIFIES ADDITIONAL REFINEMENTS

Just how successful engineers have been in reducing these losses in combustion and in the furnace, is testified for by the efficiencies of 90 and occasionally 92 per cent overall boiler efficiency obtained in the large modern stations. This is not possible or practical in small plants of course nor is it possible with all types of coal. Nevertheless it does show what can be accomplished if the price of fuel justifies the refinement of apparatus necessary.

Reduction of radiation losses from the furnace walls has been simplified, of recent years, in the larger furnaces by the large proportion of air-cooled and water-cooled walls. These losses are considerable, however, in any type of furnace and can be materially lessened by proper insulation or by completely jacketing the furnace in a casing through which the air for combustion is drawn.

Where fuel is high, obviously greater expense in preventing these losses can be justified. The customary method with the usual small or medium-sized refractory furnace is to back the usual refractory walls up with insulation of the required thickness.

All manufacturers of insulating materials have determined the heat conductivity which can be used for determining the extent and character of the insulation desired. Some refractories or semi-refractories have insulating properties in themselves and this should be considered. Losses through the floor or bottom of the furnace and top of the boiler should not be neglected.

POSITION OF FURNACE SHOULD BE CONSIDERED

Study of radiation losses especially when designing an installation should be considered in relation to the position of the furnace and condition of the surrounding atmosphere. Should the furnace be so placed that cold air currents at high velocity flows over the walls the heat losses will be considerably increased. In some cases, particularly in industrial furnaces selective painting has been used, as some paints stimulate while others retard radiation.

Of the heat absorbed by the boiler, the portion used in bringing the feedwater up to steaming temperature can be reduced by feedwater heating and the capacity of the boiler appreciably increased. For instance, a 240-lb. boiler using 100 deg. F. feedwater will absorb 1133 B.t.u. per lb. of saturated steam generated. If the feedwater temperature is raised to 200 deg. F., only 1033 B.t.u. per pound of steam will be required while if the feedwater were raised to the saturation temperature of 397 deg. F., only 836 B.t.u. would be required. With a constant heat absorption of the boiler the steaming capacity would be increased in the ratios of 1.000, 1.096 and 1.356 respectively for 100,200 and 397 deg. F. feedwater.

FUNCTION OF THE ECONOMIZER

In modern boilers utilizing steaming economizers, the boiler receives water practically at saturated steam temperature and extremely high boiler ratings are practical. Feedwater heating is accomplished by means of closed and open heaters using bled or exhaust steam and by

economizers utilizing the heat in the flue gases. One type of economizer uses an air preheater first to heat air and this air is in turn used to heat the feedwater in a special economizer. This avoids economizer corrosion due to flue gases and allows close control of the preheated air used for combustion.

Heat used in actually making the steam is the latent heat of evaporation. This varies with the pressure and decreases as the pressure increases. For instance, at 100 lb. pressure it is 888 B.t.u. per lb., at 300 lb. pressure it has decreased to 811 B.t.u. and at 600 lb. pressure it is only 741 B.t.u. per lb. At the critical pressure of 3200 lb., the latent heat is zero and water turns to steam without the addition of this extra amount of latent heat.

After the steam is made, the usual practice is to superheat it to a total temperature ranging from 500 to 750 deg. F. Central stations are ordinarily designed for the latter figure but industrial plants have not as yet universally adopted the higher temperature. Superheating is accomplished by convection and radiant type superheaters, either used separately or in combination. The specific heat of superheated steam varies with the pressure and temperature. Between 50 and 250 deg. F. superheat, the average specific heats in B.t.u. per pound are 0.506, 0.565, 0.630 and 0.725 respectively for 100, 300, 600 and 1200 lb. pressure.

Where the Steam Energy Goes

DISSIPATED BY RADIATION AND LEAKAGE, USED IN PROCESSES, WATER AND BUILDING HEATING AND IN PRIME MOVERS

ASSUMING now that a definite amount of heat has been absorbed from the furnace by the boiler water and converted into steam, we are confronted by the problem of preventing any of this carefully stored heat from leaking out of the steam before it has done useful work.

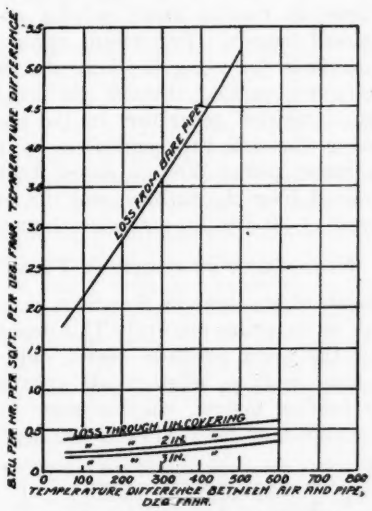

B.T.U. PER HR. PER SQ.FT. PER DEG. FAHR. TEMPERATURE DIFFERENCE
LOSS FROM BARE PIPE
LOSS THROUGH 1IN. COVERING
" " 2 IN. "
" " 3 IN. "
0 100 200 300 400 500 600 700 800
TEMPERATURE DIFFERENCE BETWEEN AIR AND PIPE, DEG. FAHR.

FIG. 1. HEAT LOSS FROM 3-IN. BARE PIPE AND PIPE INSULATED WITH 85 PER CENT MAGNESIA

About 4 per cent of the heat available in the furnace may be lost through ordinary furnace walls. So far as insulating effect alone is concerned, a solid wall of any ordinary material is usually preferable to a hollow wall of the same total thickness. In most cases, 70 per cent of this heat loss can usually be prevented by proper insulation.

RADIATION FROM STEAM-USING EQUIPMENT

Radiation from boilers, piping, valves and all steam using equipment would be enormous if they were not insulated. Figure 1 shows the heat loss from 3-in. pipe with 85 per cent magnesia covering compared with bare pipe.

Another loss in heat may occur in piping because of excessive pressure drop or excessive steam velocity in piping. This causes condensation which may produce water hammer, wet steam and many other piping troubles.

Loss of heat from underground steam lines depends, of course, on the same factors as for other lines but accounted for in a somewhat different way. Steam velocity in the pipe is sometimes as high as 10,000 ft. per min. but with other velocities the loss does not vary much. The loss in B.t.u. per hr. per foot of length of covered pipe is given by the A. S. H. & V. E. Guide as 10 per cent of that from bare pipe under the same temperature differences. Figure 2 shows types of underground steam line construction designed to prevent heat losses and proved the required mechanical construction. To reduce steam line losses, superheated steam is often used to advantage.

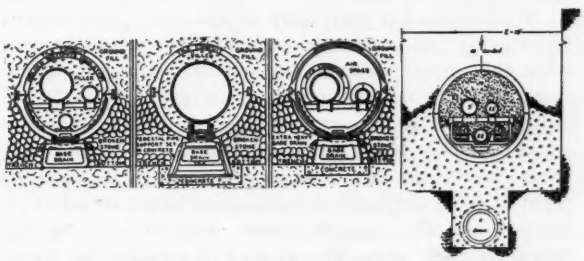


FIG. 2. TYPES OF UNDERGROUND STEAM LINE CONSTRUCTION

Engineers are sometimes in doubt as to the value of small savings of heat of the order of 10 B.t.u. The accompanying table compiled by R. H. Heilman shows the capitalized value of 10 B.t.u. From this can be determined the amount one is justified in spending to save 10 B.t.u. by insulating equipment, to secure a given return on investment.

HEAT SAVING IN PROCESS WORK

Saving of heat in process work depends not only on the way it is applied to the process but also on the care used by the operators of the process.

Automatic regulators for steam pressures, water flow controllers, heat exchangers, temperature and

CAPITALIZED VALUE OF 10 B.T.U.

Cost of fuel per 1,000,000 B. T. U	0.15	0.20	0.25	0.30	0.40	0.60
Value per year	0.0131	0.0175	0.0219	0.0263	0.0351	0.0536
Cost of steam per 1,000 lbs. 1200 B. T. U. per lb	0.18	0.24	0.30	0.36	0.48	0.72
Cost of coal per ton, 13,000 B. T. U. per lb	3.90	5.20	6.50	7.80	10.40	15.60
Cost of gas per 1,000 cu. ft. 1,000 B.T.U. per cu. ft	0.15	0.20	0.25	0.30	0.40	0.60
Cost of gas per 1,000 cu. ft. 600 B. T. U. per cu. ft	0.25	0.33	0.42	0.50	0.67	1.00
Cost of oil per gallon 152,000 B. T. U. per gal	0.023	0.030	0.038	0.046	0.061	0.091
Per cent gross return	Permissible Investment, Dollars					
6	0.218	0.292	0.365	0.438	0.585	0.877
8	0.164	0.219	0.274	0.329	0.439	0.658
10	0.131	0.175	0.219	0.263	0.351	0.526
12	0.109	0.146	0.182	0.219	0.292	0.438
14	0.094	0.125	0.156	0.188	0.251	0.376
16	0.082	0.109	0.137	0.164	0.219	0.329
18	0.073	0.097	0.122	0.146	0.195	0.292
20	0.066	0.083	0.110	0.131	0.175	0.263
25	0.052	0.070	0.088	0.105	0.141	0.210
30	0.044	0.058	0.073	0.088	0.117	0.175
35	0.037	0.050	0.063	0.075	0.100	0.150
40	0.033	0.044	0.055	0.066	0.088	0.131
50	0.026	0.035	0.044	0.053	0.070	0.105
75	0.017	0.023	0.029	0.035	0.047	0.070
100	0.013	0.018	0.022	0.026	0.035	0.053

pressure recorders—all these are invaluable aids in saving heat in processes. The engineer can often find uses in process work for exhaust steam, instead of high pressure steam direct from the boiler.

Application has been made of the steam accumulator for storing up steam exhausted from prime movers, when the process demand for exhaust steam is not synchronized with its production. Savings of 10 to 20 per cent in steam have been made in processes by use of accumulators. Many other processes benefit not only from lower steam consumption but from better pressure regulation on account of the accumulator; in addition, the overall efficiency of steam production is usually raised by their use. For storing of process hot water, storage heaters are often used.

Heat exchangers serve to recover a great deal of heat in processes. Certain hot solutions or by-products, as in corn products works, sugar plants, paper mills and the like, can be made to give up their heat to water in heat exchangers. This water may then be used in the boiler feed system, in process work or in general mill supply. Many factory processes, as in the canning industry require tremendous quantities of hot water, sometimes made by direct contact with steam, at other times in heaters using exhaust or extracted steam in closed heaters. Two recent rayon plants incorporate methods for using the heat absorbed by the circulating water passing through the condensers of the extraction turbine generators in the power plant. After passing through the condensers as circulating water, the water passes through closed heaters, using steam extracted from the turbine, and the temperature is maintained at 90 deg. by automatic controls.

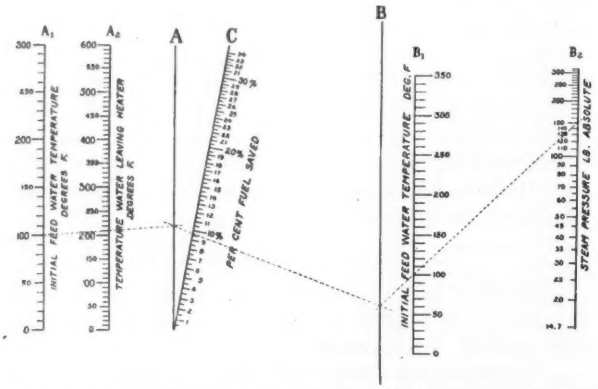


FIG. 3. PERCENTAGE OF FUEL SAVED BY HEATING FEEDWATER BY EXHAUST STEAM

Useful Work Done by Steam in Prime Movers

How much of the heat in the steam is turned into useful work in the prime movers? This depends largely on whether the plant produces power only with condensing prime movers, whether all exhaust goes to process or heating system, whether some is extracted for those purposes or for feedwater heating and so on.

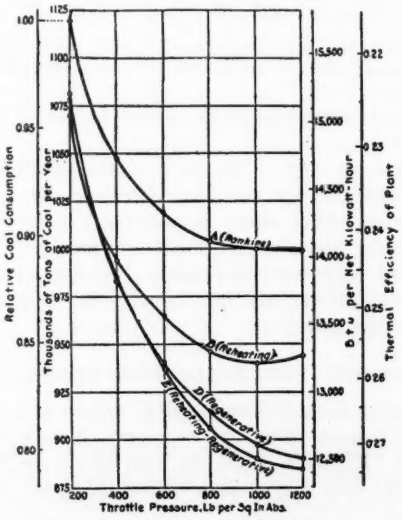


FIG. 4. EFFECT OF STEAM PRESSURE AND CYCLE ON COAL CONSUMPTION. CAP. FACT., 100 PER CENT; 200,000-KW. PLANT; 700 DEG., EXHT. 1 IN.; COAL 12,300 B.T.U.

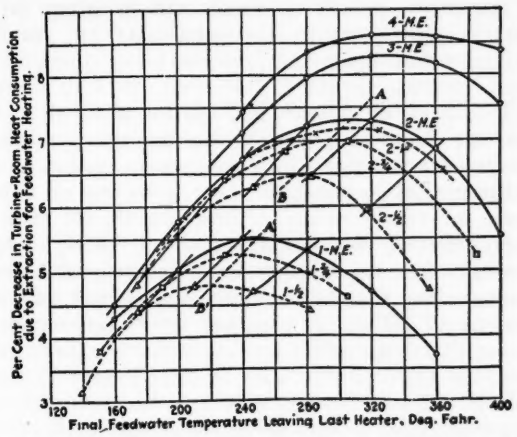


FIG. 5. HEAT SAVING BY EXTRACTION HEATING, 200,000-KW PLANT. NUMBERS 1, 2, 3 AND 4 INDICATE EXTRACTIONS AND ½ AND ¾ ARE FRACTIONS OF FULL LOAD. ME = MOST ECONOMICAL LOAD

For example, where the entire exhaust of a prime mover can be used for heating (feedwater, building, processes), power is produced on a heat expenditure of only 2545 B.t.u. as against the 12,000-15,000 B.t.u. required by many condensing turbines.

Steam pressure and temperature, number of stages of extraction for water heating, reheating of steam from the turbine for further expansion in lower pressure stages, balance between process steam and power requirements, all affect the amount of heat converted in engine or turbine into useful work.

In expanding saturated steam from 300 lb. gage to 0.5 lb. absolute or 29-in. vacuum, a perfect turbine on the Rankine cycle would convert slightly more than 34 per cent of the heat of the steam into work. The best turbines now being built are expected to realize more than 80 per cent of the ideal result, although some large steam engines have realized over 90 per cent of the theoretical. The average moderate-sized steam turbine, however, attains only about 70 per cent of the ideal.

Heat Saving by Feedwater Heating with Exhaust Steam

Feedwater heating, however, raises these values, because the heating is done by steam that has already done work in the prime mover. A single open feedwater heater operated at atmospheric pressure and receiving steam drawn from the corresponding stage of the turbine would increase the efficiency of the perfect turbine from 34 to 36.5 per cent. If the heating is done in a series of heaters, known as stage heaters, as used with modern large turbine units, the saving is large although not in direct proportion to the number of heaters.

Brown and Drewry, analyzing performance of a 28,100-kw. turbine, calculated that from one bleeder heater a saving of 5.5 per cent was realized, from two heaters 7.3 per cent, from three heaters, 8.3 per cent and from four heaters, 8.65 per cent, in net B.t.u. at the turbine throttle, giving the turbine credit for heat returned to the boiler in the feedwater.

The first and most important use of exhaust steam is in heating feedwater, since all the heat thus utilized is returned to the boilers. In general, about 1 per cent of the fuel is saved for every 11 deg. F. that the feedwater temperature is raised by heat that would otherwise be wasted. The gain is expressed by the following formula:

$$S = (t - t_o) \div [H - (t_o - 32)] \times 100$$

where S is the per cent gain in heat, H = total heat of one pound of steam above 32 deg. F., t = temperature of water leaving heater, t_o = initial temperature of the water. Figure 3 is a straight line chart showing this relation.

In Fig. 4 is shown the effect of steam pressure and cycle on coal consumption for a 200,000-kw. plant. In Fig. 5 is shown the heat saving by extraction feedwater heating.

Evaporation, Deaeration and Heating

Heat Used for These Purposes Can Be Saved by Care in Operation, Efficient Equipment and Good Insulation

RETURN of all condensate to the boilers to be used as feedwater is desirable. Where it is contaminated, separators, filters or other purifiers can be used. It is evident that since this condensate is but little below condensation temperature, it contains at least considerable heat that should be saved.

Evaporation of water as a means of saving heat is difficult to discuss aside from its value in producing good boiler feedwater or its function in evaporating materials in industrial processes.

Considering only the evaporating process itself, it is perfectly true that it is usually more efficient if evaporation is carried on in several stages. The question is whether or not the increased cost of the multiple-effect equipment is justified by the increased capacity. Not

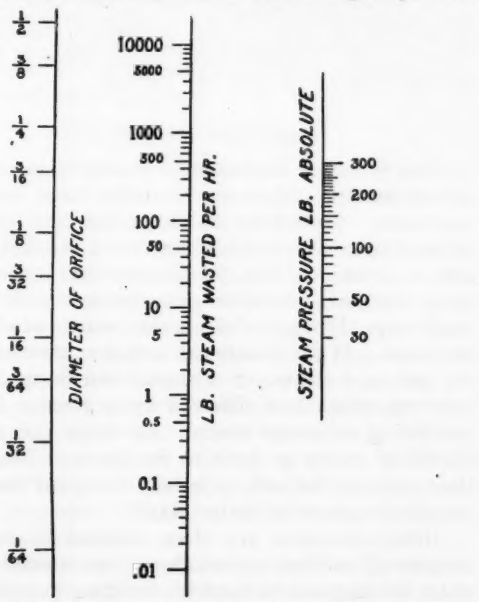


FIG. 1. CHART FOR DETERMINING QUANTITY OF STEAM WASTED BY VARIOUS SIZE LEAKS

only that but, as staging of evaporators is multiplied, initial steam pressure must also be increased.

Evaporators with Extraction Heating

In large central stations, in the average heat balance with two or three stages of extraction feedwater heating, the trend is toward single-effect units. This is because, first, the amount of makeup required is seldom over two per cent; second, with a single-effect unit, low-pressure steam that has done considerable work in the turbine can be extracted for the evaporator.

In an industrial plant that evaporates its feedwater, conditions would usually be much different since more exhaust steam would be used up in the processes, more makeup water would be required and probably multiple-effect evaporation might serve better.

In industrial process evaporators, the governing considerations are the quantity of product and steam pressure or heat drop desirable. Here evaporation in several stages is the common practice.

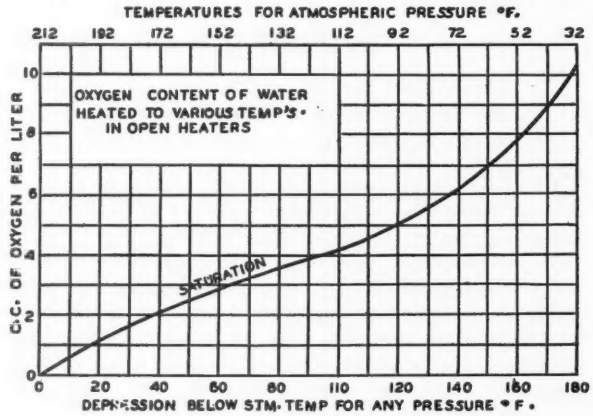

TEMPERATURES FOR ATMOSPHERIC PRESSURE °F.
212 192 172 152 132 112 92 72 52 32
OXYGEN CONTENT OF WATER HEATED TO VARIOUS TEMP'S IN OPEN HEATERS
SATURATION
C.C. OF OXYGEN PER LITER
0 2 4 6 8 10
0 20 40 60 80 110 120 140 160 180
DEPRESSION BELOW STM. TEMP FOR ANY PRESSURE °F.

FIG. 2. OXYGEN CONTENT OF WATER FROM STANDARD OPEN HEATERS

In all evaporating equipment, care should be taken to insulate all parts of the equipment and piping and to return all condensate to its proper place in the circuit so that none of its heat will be lost.

Deaeration of Feedwater

Deaeration of feedwater is practiced to remove dissolved oxygen and other corrosive gases from boiler feedwater. Extent to which oxygen can be expelled by heating water in open heaters at atmospheric pressure is shown in Fig. 2. Deaerating heaters can be used, the noncondensable gases being vented to a vent condenser through which cold water passes to the deaerator. If the deaeration is below atmospheric boiling points, a steam jet exhauster can be used with the vent condenser and followed by a gleaner heater for recovering exhauster steam. All drips and condensate should of course go back to the heater. Deaeration in the condenser hotwell, especially designed for the purpose, is practiced in many plants.

Great economies are often attained in cases where surplus of exhaust steam above that needed for feedwater heating can be used for building heating or process work. Building heating systems of various types are employed, details of which will be given later. Gravity systems return the condensate by gravity. Vacuum systems operate at pressures below atmospheric. Vapor systems operate at low pressures with devices for limitations of pressure and control of supply. All these use steam at pressures varying with conditions from below atmospheric with the vacuum system, 1 to 5 lb. for gravity systems, to vapor pressures of a few ounces for vapor systems. These can all use exhaust steam effectively when it is available. Hot water systems can often use exhaust steam, as can unit heaters in some cases although, in large unit heater systems, pressures of 200 lb. or over are sometimes employed. Air conditioning systems employ exhaust or live steam from 0 to 150 or 200 lb. gage in their tempering coils.

In all cases proper attention must be given to securing good circulation throughout the system, as otherwise heat will have to be kept on longer or more intensely in one part of the system than another. Proper pitch of mains and return lines, drips, traps and pumps to remove condensation, proper provision for eliminating air, insulation of long transmission lines and any part of the system from which radiation is not desired, noiseless return of condensation, proper control of the system as a whole or in sections where heat is most needed—all these aid in saving heat, at the same time decreasing maintenance and providing comfortable conditions for human beings.

Waste of Steam by Leaks

Steam lines and all steam using equipment should be closely watched for leaks. As shown on the accompanying chart, Fig. 1, a ⅛-in. leak at 100 lb. pressure wastes 70 lb. of steam per hour or at 50 cents per thousand pounds of steam, 84 cents every 24 hr.; not so much for one leak but multiply it by 10 leaks for 10 days and it's $84.00.

Heat loss from blowing down boilers may be considerable since the 4 to 10 per cent of the boiler water that is to be blown down to reduce the concentration has had the heat of the liquid added to it. Continuous blowdown arrangements with heat exchangers to recover much of this heat are valuable, especially in controlling concentration of certain salts. The regular blowdown is often necessary in addition, if large particles of scale are formed. With proper feedwater treatment and proper control of the boiler, however, such large particles should not be allowed to form.

Corrosion of ice cans can be controlled by the use of inexpensive chemicals. Although corrosion of old cans can be stopped after such conditions are discovered, it is well to begin the treatment with new cans immediately. This work has been carried out by the A. S. R. E., has already saved a great deal of money in can replacements and is rapidly becoming a general practice.

Sodium dichromate should be added in the proportions of 100 lb. per thousand cubic feet of calcium brine or twice this amount for sodium brine and the entire mixture maintained slightly alkaline, that is, a pH of between 7.5 and 8.5. Under these conditions, there will be little corrosion of bare or galvanized steel or iron. About half the original amount of sodium dichromate must be added each year with sufficient caustic soda or lime to maintain the desired alkalinity.

Conversion of Heat Into Work

THE SECOND LAW OF THERMODYNAMICS. FRICTION IN BEARINGS. HEATING OF GENERATORS. USEFUL WORK

IT IS SAID that when Poggendorff refused to publish Mayer's paper on the mechanical equivalent of heat, the former exclaimed, "Why, if this be true, water could be warmed by shaking it." To this, Mayer, for some time, could find no reply. The answer came only when it was shown experimentally by Joule that this was, indeed, the case. Water could be heated by shaking it. That this is true must be evident to anybody who has ever tried to operate a centrifugal pump with the discharge valve closed. Water may easily be brought to the boiling point in a comparatively short time in this manner.

All work, finally, is converted into heat, useful or otherwise. While the converse, i. e., that heat may be converted into work, is also true, it is true only to a certain extent. This is the problem presented to us by the second law of thermodynamics.

PRINCIPLE OF CONSERVATION OF ENERGY

Shortly after the establishment of the principle of the conservation of energy in the middle of the last century, and the recognition of the fact that all the different forms of energy are mutually convertible one into the other, it was also found that such conversions did not work equally well both ways; that while mechanical work or electrical energy could be converted readily and completely into heat, the reverse transformation of heat into other forms of energy could be but partly carried out. Once energy gets into the heat form it is impossible to get it all out again. This purely empirical fact, for which no theoretical necessity has ever been shown, forms the basis of the second law of thermodynamics. A little reflection will show that the consequences of this principle present to us a problem of the first magnitude, as broad and deep as the Universe.

It is this second law of thermodynamics that is responsible for the heat losses which occur in every power plant. In the power plant, heat produced by the combustion of fuels is converted into mechanical and electrical energy through the agency of boilers, turbines or engines and condensers, and generators and motors. In each of these conversion processes the entire amount of heat energy on one side is not available on the other side of the transformation; at each step, part of the heat is lost, or rather we should say, part of the energy is lost as heat. While, in many cases it is possible to reduce the amount of energy so lost, it is impossible to reduce it to zero. In other words we must reconcile ourselves to a certain loss, try as we may to reduce it to nothing. It is the function of those who design and operate power plants to reduce these losses to the absolute minimum.

Heat energy converted into work is lost in various ways. First, heat is lost by friction in bearings and between the reciprocating parts of mechanical equipment as well as in the windage and turbulence of air or fluids surrounding moving equipment. This loss should be kept down by providing proper lubrication and by using well designed equipment.

Second, heat is lost in the heating of motors, transformers and electric control equipment. This loss, perhaps, is also due to a sort of friction occurring in the metallic conductors due to the resistance offered to the passage of current. This loss, as a rule is not subject to the control of the power plant operator except insofar as he may be able to provide means for its reclamation. Usually, the heat loss of such equipment is a feature considered in the design of the equipment, therefore, not subject to control after the machine is built. By operating the machines at the most economical point on the load curve and by reclaiming part of the heat, this loss may be reduced.

The total heat minus the losses which occur at various stages in the transformation, is available for doing useful work in lighting, heating and furnishing power. While this utilization of power is not always subject to the supervision of the plant engineer, in many cases he can offer advice and suggestions which will conserve this power to the best economical advantage. Where the utilization of power is under his direction as it often is, he can reduce losses by using efficient equipment, cutting out needless load and operating at the point of best efficiency.

In considering this whole subject of heat saving, it must be understood thoroughly, that wherever energy undergoes transformation, there is a tendency for a part of it to leak away as heat. A thorough knowledge of the manner in which this heat is produced and the laws which govern this production will enable one to devise means for reducing the losses.

FRICTION OF BEARINGS

Friction is defined by Rankine as that force which acts between two bodies at their surface of contact so as to resist their sliding on each other and which depends on the force with which the bodies are pressed together. Bearings are usually so designed that the area of contact between the shaft and the bearing is sufficient to keep the pressure between unit areas below a safe maximum. Assuming this to be the case, excessive friction in the bearings of any machine may be due to either or a combination of the following causes: Grit or foreign matter in the bearing or in the oil, improper oil, worn or scored bearings or shafts, misalinement of bearings or distorted shafts, high or low temperatures, improper adjustment of bearings, insufficient oil, and excessive speed.

It is unnecessary here, to discuss these factors in detail as they are more or less self-evident, as are their remedies. The existence of any of these conditions will

exhibit itself in a rise in temperature of the bearing. While small bearings are not fitted with thermometers and oil pressure gages as are large bearings, their temperature must be determined at frequent intervals by feeling them with the hand. Experience will soon tell whether or not the bearing is operating properly.

Curing an Overheated Bearing

The treatment of a heated bearing involves two chief items, the removal of the cause and the restoration of the bearing to its normal condition.

Of course, the machine may be shut down, and in case of excessive temperature this procedure may be necessary. In some instances, the heating may be decreased by slowing down somewhat, thus decreasing the amount of work thrown on the bearing. It may be decreased further by easing up on the bearing caps, thereby increasing the clearance between the journal and the bearing surface. This, however, can be done only to a slight extent, otherwise further trouble will result due to too great clearance and consequent pounding.

Increasing the supply of lubricant will aid in decreasing the cause, as will also a decrease in temperature brought about by forced cooling. To this end, in an extreme case it may be considered necessary to turn a stream of water on the bearing. In the case of an electric motor or generator, however, this method can not be used as water will damage the windings. Water should not be used unless absolutely necessary, for it is almost certain to find its way in and on the bearing surfaces where it will prevent the action of the lubricant.

In modern bearings on large machines, provision is made for circulating water through hollow bearing blocks or through coils imbedded in the bearings. This is the most effective method of cooling bearings and in case of an undue temperature rise in this type of bearing the circulation of water can be increased or its temperature decreased.

In case the equipment is not properly lined up or the bearings are not in proper condition, only temporary relief can be looked for from the various means suggested above. Of these means, the most effective is the operation of the machinery at low or moderate power until such time as the needed readjustments or repairs can be made.

In an endeavor to reduce the friction load in bearings to a minimum, antifriction bearings have been developed and for many purposes these present many advantages. There are two distinctive types in use, namely, the ball and the roller, each possessing its own individual characteristics. The use of these bearings has proved so satisfactory in recent years that even though they are much more costly than babbitted bearings their use is justified by the reduction of friction load they effect and by the saving in oil and wear.

Heat Losses in Electrical Equipment

In order to keep the heat loss in electrical equipment down to a minimum, it is essential that the machines be operated at the point of best efficiency. Small equipment is usually designed to have sufficient radiating surface to dissipate the normal heat loss but in large machines (alternators, motors and transformers) forced ventilation is necessary to keep the temperature of the hottest part down to 125 deg. C. Most turbine generators today are equipped with closed ventilating systems through which the air is circulated continuously and cooled by a spray or tubular cooler. In this case the heat loss in the windings is abstracted by the water in the air cooler, and it may thus be reclaimed. In the past it was the practice to pass the condensate from the main condensers through such coolers, thus slightly raising the temperature of the feedwater, but this practice is dying out. In other instances air was drawn from outdoors, through the generator windings and then delivered to the boiler furnaces. The amount of heat reclaimed in this manner was slight, however, and with the advent of the modern air preheater, this method is not being used in new installations. At the present time the practice is to use circulating water for the generator cooling system, the slight heat recovery in the water being considered of negligible value in stations designed along modern lines.

Operating for Economy

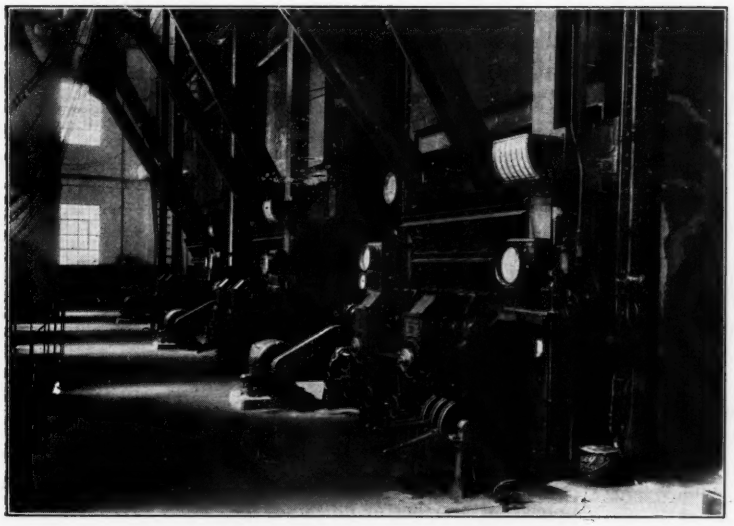
For best economy, electrical equipment should be operated at the point of highest economy on the load curve. Under certain conditions it may often be necessary to operate electrical equipment at loads in excess of the normal rated capacity for limited periods of time. This is permissible if the time a machine is so operated falls within the limits specified by the manufacturer, but under no conditions must this time limit be exceeded. The reason for this is not the mere fact that the heat loss is increased by overload operation but that the insulation of the machine may be damaged.

The problem in the design and operation of electrical machinery is not only to reduce the heat losses to a minimum but to provide proper means for radiating the heat generated in the machine without subjecting any part of the windings to excessive temperature. This is often difficult because the insulation of electrical windings is generally a poor conductor of heat and instead of transmitting the heat to the air, it tends to retain it.

During recent years, extensive experiments have been made in the ventilation of high capacity generators and converters by gases other than air. The use of hydrogen in this manner seems to offer attractive possibilities and while no generators using hydrogen as the cooling medium are in service, several rotary converters have been operating successfully in atmospheres of hydrogen. Hydrogen is not only a very much more effective radiator of heat than air but it is also lighter and for this reason the friction and windage losses are less.

Sulphur has long been considered as a determining factor in the fusing point of coal ash or slag. Recent determinations show that this is not true, however, a number of tests on coal with ash contents of less than one per cent showing a fusing temperature of ash varying from 1900 to 2950 deg. F. As the sulphur content increases, the temperature variation is less, probably due to the few fields from which samples were obtained. There is no evidence, however, to show that sulphur can be taken as an indication of the fusing temperature.

CONDITIONS PROPITIOUS for HEAT SAVINGS



Good Fuel
Correct Firing
Regulated Air Supply
Combustion Control
Suitable Insulation

Proper Fuel Necessary for High Efficiency

TO OBTAIN BEST RESULTS, PHYSICAL AS WELL AS CHEMICAL PROPERTIES OF FUEL MUST BE CONSIDERED IN RELATION TO FURNACE AND GRATE

SELECTION of the proper fuel to use in a given or proposed plant depends largely upon geographical limitations. In each district there are usually several coals available at about the same price. Today there is no excuse for the misapplication of stokers or methods of firing because types are available to meet all load or fuel conditions.

In an existing plant where the available fuel must be fitted to the plant rather than the plant to the fuel, the selection of the coal to be used is a large factor in the possible heat saving in the plant.

To a certain extent, the character of a coal can be predicted from the proximate analysis, that is, a determination of the moisture, ash, fixed carbon, volatile matter and usually but not always, sulphur and heat content. True, coals from different fields have widely varying physical characteristics which cannot be determined from the proximate analysis but if correctly done this analysis helps identify the field from which it comes. Coals from the same field will show a constant heating value when calculated on a moisture and ash free basis.

For example, Pocahontas 15,000, Pittsburgh 15,500, Colorado anthracite 15,100, Illinois 14,500 and Colorado lignite 12,000 B.t.u. per lb. are typical values of heat content on a moisture and ash free basis. Conversely, knowing the field from which the coal comes, the typical heating value can be used to check the accuracy of the analysis.

VOLATILE COALS REQUIRE LARGER FURNACES

The ratio of fixed carbon to volatile determines to a large extent the size and type of furnace necessary. Fixed carbon burns largely on the grate while the volatile burns in the furnace above the grate. Generally speaking, low volatile coals are better adapted to stoker or hand firing while high volatile coals are preferable for pulverized coal fired plants. In a given plant, with limited combustion space a low volatile coal would usually be preferable.

Ash and moisture are of no value. In fact, they may be serious liabilities, especially if the plant is far from the mines and the freight rate high. Usually the price of the coal takes into consideration the moisture and ash content but even this still leaves freight and handling charges to be considered.

In addition to the direct cost, moisture and ash are sources of heat loss in the furnace through superheated water vapor in the exit gases and combustible carried over in the refuse. Of course an extremely low ash content may be just as objectionable as an extremely high ash content, especially with stokers. The ash and refuse protect the rear end of the stoker from radiant heat and prevent excessive grate maintenance due to overheating.

There are coals, for instance the Arkansas anthracites, which have so little ash it is difficult if not impossible to burn them without high stoker repairs. Chain grate stokers give best results from 10 to 15 per cent ash, underfeed stokers with from 7 to 12 per cent ash while, with hand firing, the ash may run as low as 5 per cent.

Three Types of Coal

In addition to the properties shown by the proximate analysis, coals from certain fields exhibit certain physical characteristics which largely determine the best type of fuel burning equipment. With respect to their behavior in the fire, coals can be divided into three classes: coals that coke and fuse into masses; coals that burn free without much change in shape of the individual pieces and coals that disintegrate into small pieces.

The first class coking coals are best adapted to hand firing, underfeed stokers or in pulverized form. The fuel bed must be agitated periodically in order to break up the masses of coke and let the air through. As pulverized fuel, the carbon losses in the flue gases are likely to run high. Most Eastern and Appalachian coals come in this class.

Free burning coals change their shape and size but little and are adapted to all types of firing, although they are particularly well adapted to the chain grate stoker. Most of the middle western coals belong to this class.

Sized Coal Gives Better Results

Slacking coals are the high moisture content, subbituminous and lignites of the western states. They burn well on grates, on traveling grate stokers and in pulverized form but combustion rates are relatively low.

Types of stokers generally considered best adapted to the several types of coal are listed in the accompanying table. This does not mean that other types of stokers cannot be used or are not used; the table merely indicates general practice.

Fuel	Stoker
Anthracite	Forced draft traveling grates
Semi-anthracite	Forced draft traveling grates
Coke breeze	Forced draft traveling grates
Semi-bituminous, coking	Underfeed and overfeed
Bituminous, coking	Underfeed and overfeed
Free burning, 10 to 12% ash	Forced or natural draft traveling grates
Free burning below 10% ash	Traveling grates, underfeed or overfeed
Sub-bituminous	Forced or natural draft traveling grates
Lignite	Forced or natural draft traveling grates

Anthracite and coke breeze are limited practically to forced draft because of the dense fuel bed which they make. With the other fuels, the choice of forced or natural draft is largely dependent on the nature of the load and ratings needed.

With any types of grates, sized or screened coal gives better results than run of mine or screenings. Ash is usually lower, less effort is required on the part of the fireman, the fire bed is loose and burns uniformly without holes, making higher ratings, more uniform operation and better efficiency possible.

Firing Method Must Suit Coal and Equipment

Details of Firing Methods That Prevent Heat Losses with Hand Firing, Underfeed and Overfeed Stokers and Traveling Grate Stokers

VARIATIONS IN available fuel as well as local load and labor conditions determine to a large extent the type and arrangement of fuel burning equipment selected. Results attained in any particular instance, however, will depend primarily upon the skill and diligence of the fireman.

With all types of equipment from stationary grates through to the modern forced draft automatically controlled stoker or pulverized coal firing, the function of the fireman is the same, that is, to obtain the necessary amount of steam with the minimum amount of fuel. This means uniform and regular coal feed and a clean fire without holes.

Heat losses, or potential heat losses, take place in a number of ways and it is the duty of the fireman to reduce these losses to the minimum possible consistent with the boiler rating necessary and the types of coal and firing equipment. Air supply, coal feed and fuel bed thickness must be adjusted so as to obtain small losses in combustible in the ashpit or in the flue gases.

With the same type of equipment, different coals require different treatment or methods of firing in order to obtain the best results. Naturally, the methods of firing applicable to one type of equipment such as a chain grate stoker differs radically from that which must be followed with another type, say a multiple retort underfeed stoker.

Hand firing is still common in small plants and if well done will give good efficiencies. Sometimes stationary grates and sometimes shaking grates are installed. At least five different methods of firing are in use although some of these differ only in detail. These methods are known as the ribbon, alternate, spreading, spot and coking methods.

In ribbon firing, coal is fired in narrow alternate strips extending the full length of the furnace. If these strips be extended to half the width of the furnace, ribbon firing becomes the same as alternate firing. In a small furnace half the grate can be covered at a time by the alternate method but on large grates, especially those with three firing doors, the method shown in Fig. 1 is preferable. As recommended by the Bureau of Mines, with this method the furnace of this type, Sections A_1 and C_1 at the rear half of the grate areas and opposite the two end doors and B_2 at the front half of the center section are covered at one firing and sections A_2, C_2 and B_1, the remaining areas, covered at the next firing. Proper firing by the alternate method on shaking grates is shown in Fig. 2. As the fire bed builds up, the ash must be partially removed by gentle shaking of the grates, although sufficient should be left to keep the grate bars from burning.

In the spreading method, small quantities of coal are spread evenly over the entire grate beginning at the bridge wall and working forward. Spot firing is an adaption of this method, in which small quantities of coal are fired on the low or burned out spots and the fuel bed kept uniform and even without disturbing it with tools.

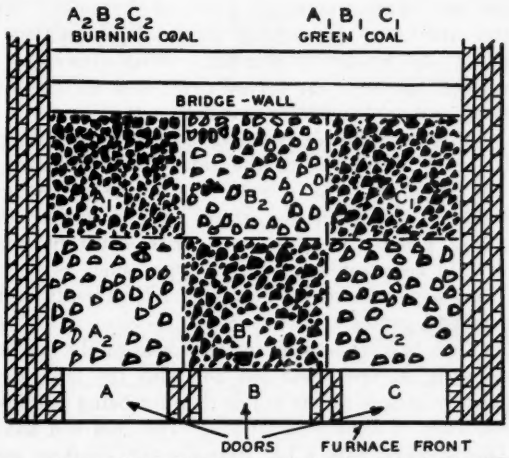


FIG. 1. ALTERNATE FIRING IN A THREE-DOOR FURNACE

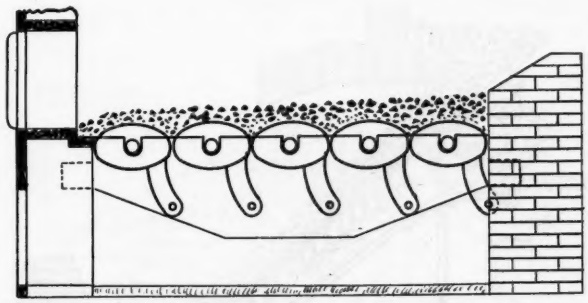


FIG. 2. APPEARANCE OF THE FUEL BED WITH ALTERNATE FIRING AND SHAKING GRATES

In the coking method fresh coal, fired to a considerable depth on the dead plate at the front of the furnace, is allowed to coke. This coke is then spread over the entire grate before more coal is fired at the front. Figure 3A shows a fire properly prepared for firing by the coking method. The ash has been shaken out and the burning fuel or coke moved toward the back of the furnace. This movement should be done carefully with the hoe to avoid mixing and stirring as much as possible. The coal is fired as shown in Fig. 3B. The amount of coal fired should depend upon the demand for steam. When it is burning all over the fire it can be moved back as shown in Fig. 3A and the cycle repeated.

With low volatile coal, any of the four methods can be used with good results but with the high volatile bituminous and lignite coals smokeless combustion is not so easily achieved. Of the four methods, the spreading is in general the least desirable method and because of the usual firing door arrangement, the ribbon is the most difficult so that the alternate and coking methods are generally considered standard.

In both methods, smokeless combustion results from the firing of raw coal in small quantities in such a location that the volatiles distilled from the new coal are forced to pass over and mix with the hot gases from the brightly burning sections in order to burn the heavy hydrocarbons before they break down and form soot.

With anthracite, a thin fire should be carried because of the dense fuel bed formed. The alternate method gives good results with this type of coal. Good grades of non-coking bituminous coal can be fired by any method but the coking varieties should be fired by the coking method for best results even though this method entails considerable more work for the fireman because he has to handle the coal twice.

Some of the volatile slagging coals can be fired successfully only by the spot method but it requires considerably more skill than the others. When the door is opened, the fireman must determine at a quick glance the spots which need coal. Some coking may be necessary to break up the lumps of coke but the fuel bed should not be disturbed, nor should the holes be levelled by tools. If holes develop, they should be filled by several light firings.

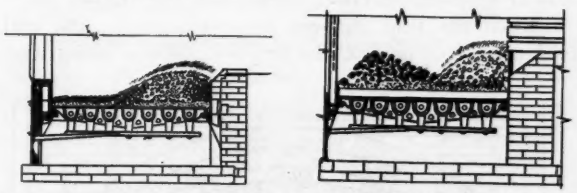
With hand stokers, coal is fired at the upper end of the grate and gradually worked down to the dead plate by hand operated pushers. Figure 4 illustrates the condition of the fuel bed just after firing on an inclined hand stoker.

Green coal is fired 10 to 12 in. deep on the upper end of the grate. This bank of green coal should start at the edge of the dead plate and extend down about 18 in. This coal is allowed to coke until time for the next firing. Before putting on a new charge, the semi-coked coal should be pushed with a short handled hoe or back of the shovel, down onto the pushers.

Care must be taken not to push the coal on top of the incandescent coal at the bottom as this will cause smoke or clinkers. The bed of coke on the center of the grate bars is worked down by means of the pushers, which should be worked only often enough to keep the holes in the fire covered. The thickness of the fire should be governed by the draft and load carried. Holes and bare spots should not be allowed.

Overfeed Stokers

Overfeed stokers are similar in operation, details of the various types and makes differing somewhat both



FI. 3. A. FIRE PROPERLY PREPARED FOR FIRING BY THE COKING METHOD. B. THE CHARGE OF GREEN COAL JUST AFTER FIRING

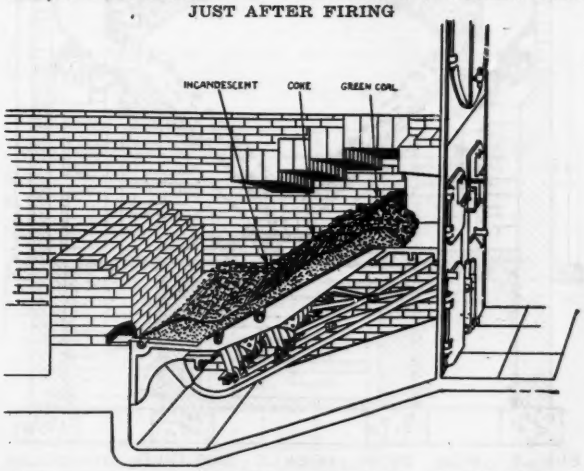


FIG. 4. A WELL KEPT FIRE ON A HAND STOKER JUST AFTER FIRING

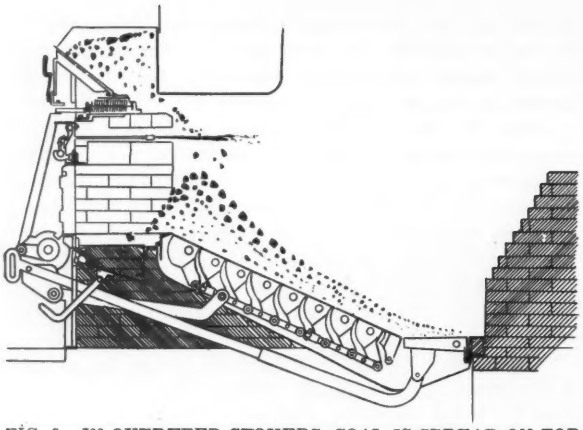


FIG. 5. IN OVERFEED STOKERS, COAL IS SPREAD ON TOP OF THE FIRE

in design and operation. Figures 5, 6 and 7 represent three different types. Figure 5 is a true overfeed with the coal fed on top of the fire at the front end of the grate. Sometimes the coal drops off the fuel plate by gravity, sometimes it is distributed by steam jets, (a popular design of locomotive stoker) while sometimes it is distributed by rotating hammers. Figure 6 is a typical overfeed stoker of the side feed double inclined type where coal is fed into both sides of the furnace while Fig. 7 is an overfeed stoker of the single inclined front feed type with coal fed from the front of the furnace only.

With the side feed double inclined stoker, the fuel bed thins down from 8 to 10 in. at the upper ends of the grates toward the clinker grinder at the bottom. Fire on the lower end of the grates should be kept active and relatively thin by means of the movable grate bars. Minor fluctuations in load can be taken care of by variations in the draft over the fire.

When the load changes are considerable, the coal feed must be changed, the draft variations being used to take care of the immediate needs of the boiler. With natural draft, the air supply should be regulated by means of the breeching damper. With this type of stoker, fires are thin for forced draft and require close attention to keep the grates covered.

Combustion rates on overfeed stokers can be changed by the rate of coal feed, the rate of ash removal or changes in draft. As a rule, the stroke of the coal pushers and action of the grates can be varied, thus providing great flexibility even with constant speed drive. On constant speed drive types such as Fig. 7, coal feed is regulated by means of adjustments of the pushers and grates.

On stokers of this type, the thickness of the fuel bed varies with the coal used but not with the load, draft changes by means of the boiler damper being employed to take care of load fluctuations. The fuel bed should not be disturbed with a bar unless severe clinkers make this imperative. Such disturbance tends to cause avalanching of the coal. When starting a fire from a banked condition, however, it is desirable to break the crust with a bar.

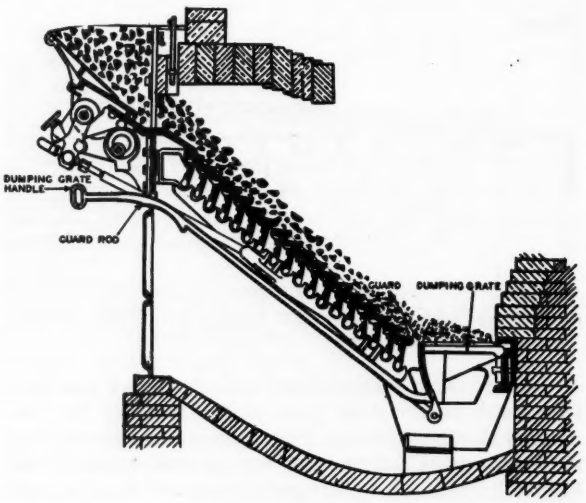


FIG. 7. ON THIS TYPE OF FRONT FEED OVERFEED STOKERS, A CONSTANT FUEL BED THICKNESS IS CARRIED AT ALL LOADS FOR BEST OPERATION

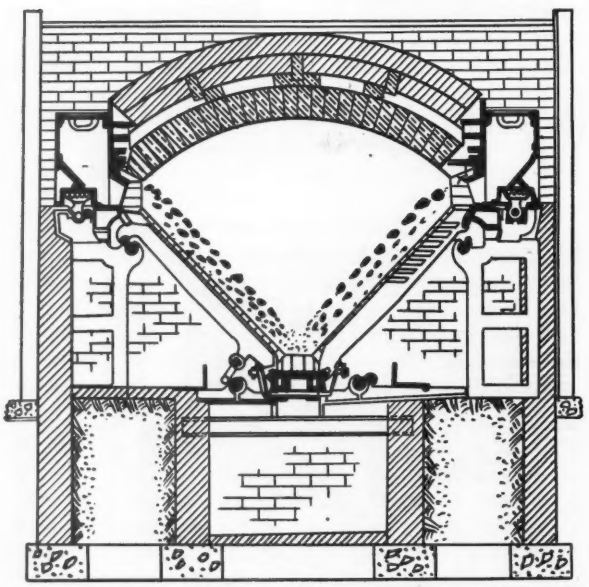


FIG. 6. SIDE FEED DOUBLE INCLINED OVERFEED STOKERS HAVE CLINKER GRINDERS TO REMOVE THE ASH FROM THE FURNACE

Underfeed Stokers

Underfeed stokers operate on an entirely different principle from the overfeed types, the fresh coal being fed up from underneath through retorts. Some stokers of this type have a single retort fed by means of a screw as in Fig. 8 or by a pusher and auxiliary blocks as in Fig. 9 while the larger type has several such retorts as in Fig. 10, the ash being discharged continually and off the end of the stoker. Stokers of this kind are all of the forced draft type although they can be run at low ratings on natural draft in emergencies.

Regulation of underfeed stokers is accomplished by means of the rate of coal feed or by changing the amount and the distribution of the air. Control of the fuel bed is by means of the secondary coal feeding arrangement and it is essential that the fuel bed be adjusted so that coal emerges from the entire length of

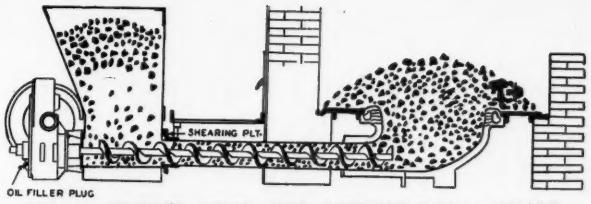


FIG. 8. PROPER FUEL BED OUTLINE FOR A SMALL UNDERFEED STOKER

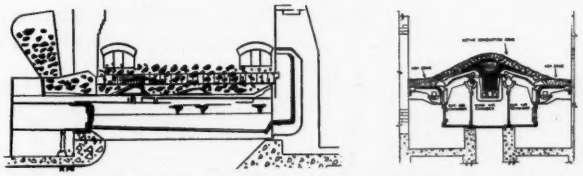


FIG. 9. ON CENTER RETORT UNDERFEED STOKERS OF THIS KIND, THE ACTIVE COMBUSTION ZONE SHOULD EXTEND OUT TO THE DUMP PLATES

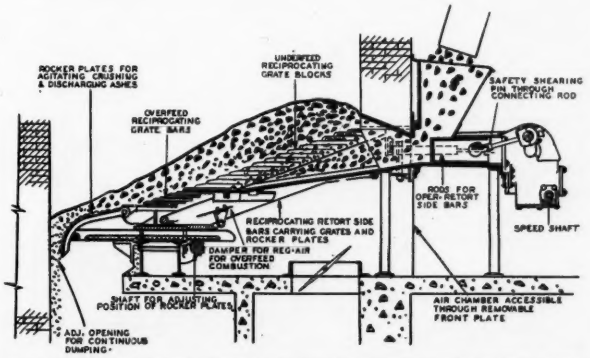

ROCKER PLATES FOR AGITATING CRUSHING & DISCHARGING ASHES
UNDERFEED RECIPROCATING GRATE BLOCKS
SAFETY SHEARING PIN THROUGH CONNECTING ROD
OVERFEED RECIPROCATING GRATE BARS
RODS FOR OPER. RETORT SIDE BARS
SPEED SHAFT
RECIPROCATING RETORT SIDE BARS CARRYING GRATES AND ROCKER PLATES
DAMPER FOR REG. AIR FOR OVERFEED COMBUSTION
SHAFT FOR ADJUSTING POSITION OF ROCKER PLATES
AIR CHAMBER ACCESSIBLE THROUGH REMOVABLE FRONT PLATE
ADJ. OPENING FOR CONTINUOUS DUMPING

FIG. 10. MULTIPLE RETORT UNDERFEED STOKERS GIVE CLOSE CONTROL OF THE FUEL BED AND COMBUSTION

the retort although a somewhat lesser amount should be fed to the rear end on multiple retort models. In general, the greater the ash in the coal the longer the stroke of the secondary feed feeding mechanism.

If insufficient fuel is fed to the lower end, the ash, which is not properly discharged, clinkers and is later covered with fuel fed down above, causing avalanching. This condition can be eliminated by proper adjustment of the secondary coal feeding mechanism. This adjustment changes for different kinds of coal and although extremely important usually receives little attention from the operators.

With this type of stoker, the fire should never be broken up and disturbed with a slice bar as is done in hand firing. It should not be necessary to disturb the fire nor the grate except to level up large holes. This can be done with the back of a hoe or rake.

Traveling Grate Stokers

Chain grate stokers are made for both natural and forced draft, the coal being fed onto the front of the stoker in a continuous comparatively thin layer, the purpose of the stoker being to burn the fuel completely by the time it reaches the rear end.

Combustion on a chain grate stoker can be regulated by the thickness of the fuel bed, the speed or by the draft. In general, the best fire to carry will be the thinnest possible without losing operation or blowing the coal off the grate. If the load fluctuates greatly the fire will have to be carried thicker than would otherwise be advisable.

If the coal is dry, it should be tempered or wetted before reaching the bunker so that the moisture will be well distributed. The amount of moisture varies with the coal, some coals requiring up to 10 or 12 per cent moisture for best operation. If no provision can be made for tempering in advance, introduction of exhaust steam into the feed spout or stoker hopper will help.

It is seldom that a stoker is operated at its maximum rating and with stokers with dampers there is no necessity of running a full length fire. On light loads, a short fire with the rear compartments closed is best. Once the proper thickness of the fire is determined, the feed gate should not be disturbed. This setting is more a function of the coal used than of the load carried.

In general, for front arch constructions and zoned stokers the highest draft should be carried in the first compartment with a gradual decrease in the secondary zones. At light loads, the draft in the last one or two compartments may be cut off entirely. With rear arch settings, conditions are almost reversed and the heaviest draft will be carried approximately under the middle of the arch, gradually decreasing toward the front.

It must be thoroughly understood, however, that no general directions for operating a particular piece of equipment can be given and detailed directions should always be obtained from the manufacturer.

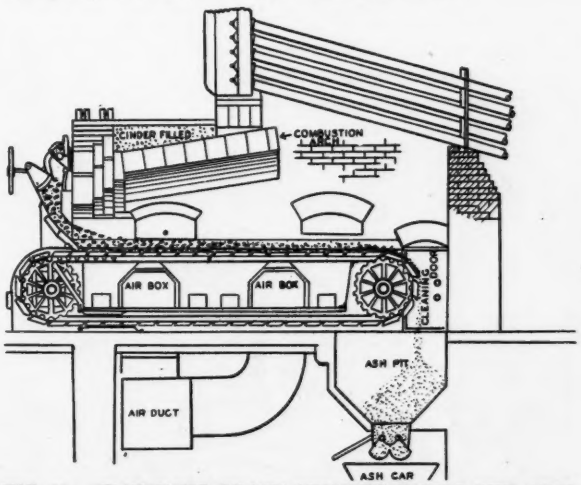


FIG. 11. TRAVELING GRATE STOKERS CARRY THE FUEL BED FORWARD CONTINUOUSLY AND COMBUSTION SHOULD BE COMPLETE AT THE REAR END

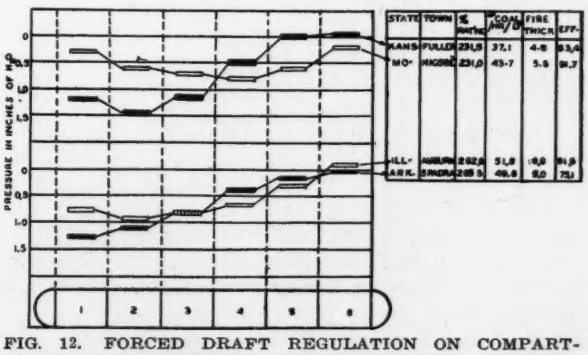


FIG. 12. FORCED DRAFT REGULATION ON COMPARTMENTS OF TRAVELING GRATE STOKERS DEPENDS LARGELY UPON THE TYPE OF COAL USED

Saving Heat in Pulverized Coal Firing

PREVENTING ESCAPE OF GREEN COAL AND PULVERIZED FUEL FROM SYSTEM, PROPER BURNERS AND CORRECT PROPORTION OF FUEL AND AIR

TWO SYSTEMS of burning pulverized coal are in use: the unit system and the central or bin system. In the modern central system, coal is dried usually in the mills by the preheated primary air that is usually introduced there. In some of the older systems and in one or two built recently, a separate dryer uses flue gas or steam to dry the coal, primarily so it can be transported without trouble. From the pulverizing mills, coal is blown to the burners, sometimes direct from the mill and sometimes by a separate exhauster. In central systems, an arrangement of cyclone collectors is often used.

Burners are usually of the turbulent type, the principles of their operation being shown in Figs. 1 and 2.

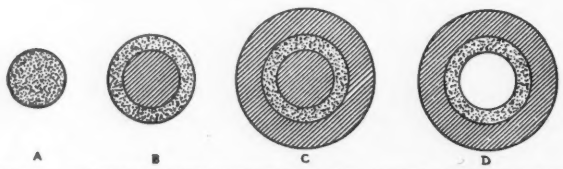


FIG. 1. POSSIBLE RELATIONS OF AIR AND COAL STREAMS IN BURNERS. DOTTED PART IS AIR AND COAL, SHADED PART AIR ALONE

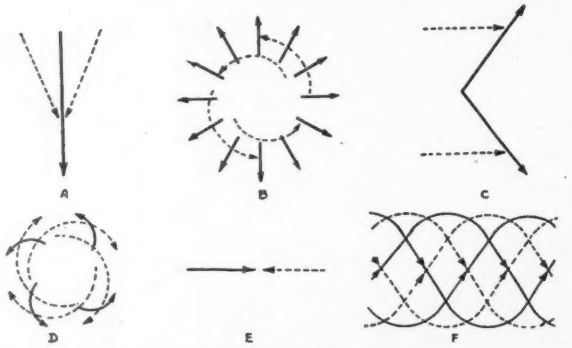


FIG. 2. METHODS OF INDUCING TURBULENCE IN BURNERS. FULL LINE, PRIMARY AIR AND COAL; DOTTED LINE SECONDARY AIR

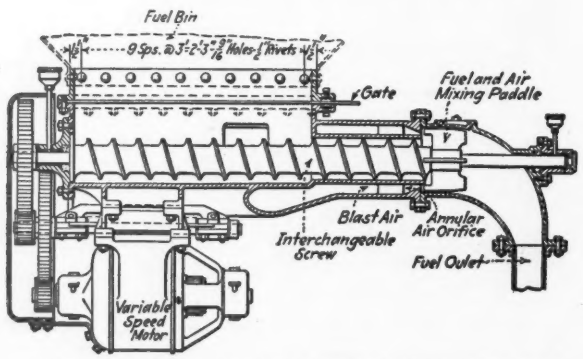


FIG. 5. SCREW TYPE PULVERIZED COAL FEEDER

Figures 3 and 4 show the principles of operation of several types of feeders that supply coal to pulverizing mills. These are important because uniform and unfailing feed of coal by the pulverizer is necessary. In central systems, pulverized coal is often pumped from the mills by screw pumps or compressed air systems to pulverized coal bunkers from which screw feeders of the type shown in Fig. 5 supply it to the burners. Another type of feeder consists of a horizontally-revolving paddle that pushes uniform amounts of coal through an orifice in a plate.

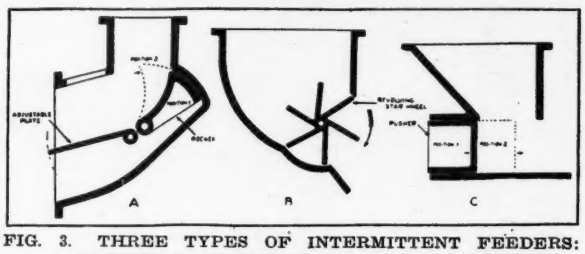


FIG. 3. THREE TYPES OF INTERMITTENT FEEDERS: A, ROCKER; B, REVOLVING POCKET; C, PUSHER

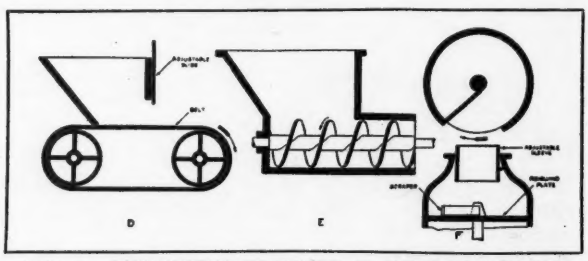


FIG. 4. CONTINUOUS FEEDERS: D, BELT; E, SCREW; F, REVOLVING PLATE

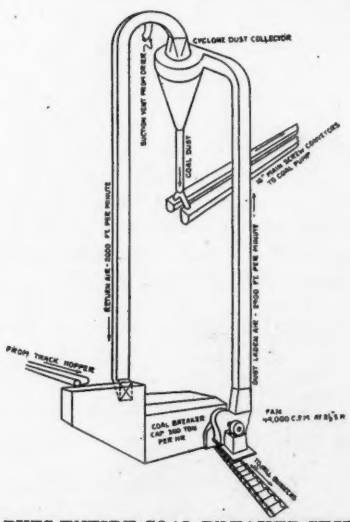


FIG. 6. FAN PUTS ENTIRE COAL BREAKER SYSTEM UNDER SUCTION, RECLAIMING 4½ T. OF COAL AN HOUR

Preventing Loss of Coal from System

Loss of available heat may occur in pulverized coal systems from loss of green coal or of pulverized coal escaping from the system. Another loss may occur if the proper proportions of air and pulverized coal are not maintained at the burner for good combustion. Loss due to moisture in the coal is a combustion loss, discussed elsewhere in this issue.

With unit mills, there is no storage of coal between mill and burner, therefore the principal precaution to prevent loss is to see that no pulverized coal dust is left in the system when it is shut down, as it might lead to an explosion in some way. Large central systems are sometimes kept entirely under suction by a fan, or the exhausters and cyclones arranged to produce suction so that no pulverized coal can escape to the room. Figure 6 shows the method used in a large central station; the 49,000-c.f.m. fan keeps the entire breaker system under slight vacuum, thus discharging pulverized coal and coal dust to the conveyor supplying the pulverized coal pumps. This amount, about 4½ t. an hour, would have otherwise entered the room, producing a fire hazard and a waste of coal.

Proper Air-Fuel Ratios Decrease Heat Loss

Air supply to burners must be at proper temperature; in modern plants, the temperatures of primary and secondary air range from 200 to 400 for primary and 200 to 500 for secondary. Modern practice is to introduce from 10 to 25 per cent of the air as primary air and the remainder as secondary, although a few plants use as much as 60-70 per cent of primary air at the mill.

Primary air pressures are usually between 5 and 15 in. H_2O with some large units needing as much as 25 in. Secondary air in many modern plants is from the forced draft ducts.

Precautions to prevent waste of coal, insulation of air ducts to prevent radiation, proper care in operation of burners to secure proper relation of air and coal—these are the chief methods of preventing loss of heat in the feeding of pulverized coal.

Proper Air Supply Promotes Good Combustion

To Provide Proper Amount of Air at Proper Temperature and Pressure, at the Same Time Avoiding Heat Loss, Various Types of Fans and Control Methods Are Used

DRAFT FOR BOILER furnaces, which costs money to produce, is needed to cause flow of air through the fuel bed, also to carry the gaseous products of combustion to and out of the chimney. Resistance offered to the flow of air for combustion includes, first, air-duct friction, second, resistance of the fuel bed, which is dependent upon the size of fuel, depth of fuel bed, rate of combustion and nature of the fuel, particularly as to ash content and tendency to form clinker.

Causes of Draft Loss

Resistances offered to the flow of flue gases are affected by the type of boiler, type of boiler setting, arrangement of baffles, length and design of breeching, accumulations of soot and ash and rate of operation.

Any resistance to the air or gas flow, or air leakage which "breaks draft" brings need for increased draft. Air leaks occur through cracking of the setting due to expansion and contraction and through spaces around clean-out doors. This is bad. No air should enter the furnace except such as is available for the combustion process.

Detection and Elimination of Leaks

Air leaks in a boiler setting may be detected by applying a lighted candle to all suspicious cracks while the boiler is operating. The flame will be sucked in at all openings in the setting beyond the grate. All such openings must be closed and for this purpose a flexible cement such as magnesium-asbestos-asphalt mixture is much better than cement mortar because the latter is likely to crack in hardening. Cotton waste, pulled apart and stirred into very thin fire-clay mixture, works well as a calking material. The following compositions will make a suitable heat-insulating paint having elastic properties sufficient to eliminate cracking and with sufficient body to seal all small cracks: Trinidad or Bermuda asphalt, 10 lb.; benzine, 1 gal.; Portland cement, 7½ lb.; and a mixture of 85 per cent magnesia and 15 per cent asbestos, 7½ lb. Closing of large cracks can best be accomplished by first ramming sufficient asbestos into the openings and then sealing them with a flexible cement.

Draft may be natural, which is usually accomplished by means of a stack; or mechanical, which utilizes some external means to raise the pressure of the air under the grate as in the case of forced draft or of the flue gases beyond the boiler as in the case of induced draft; last, we have balanced draft which combines the forced and induced draft systems. Typical requirements for natural draft are shown in the following table.

NATURAL DRAFT REQUIREMENTS

Combustion Rate per sq. ft. of Grate in lb. per hr.	Draft in inches of water	
	Bituminous coal	Anthracite coal
5	0.02-0.04	0.06-0.16
10	0.05-0.10	0.16-0.40
15	0.07-0.15	0.30-0.75
20	0.10-0.25	0.45-1.25
25	0.12-0.32	0.65
30	0.17-0.45	0.90
35	0.21-0.58	
40	0.27-0.75	
45	0.32-0.95	

Requirements for mechanical draft are illustrated in Fig. 1.

Air Is Required for Each Combustion Stage

Since combustion of coal takes place in three stages, in order to maintain good combustion, it is necessary to supply air in sufficient quantity for each of these stages. As gases which are distilled from the coal are burned after leaving the grate and should be completely burned before reaching any heating surface, over-fire air must be supplied at points above the fuel bed in

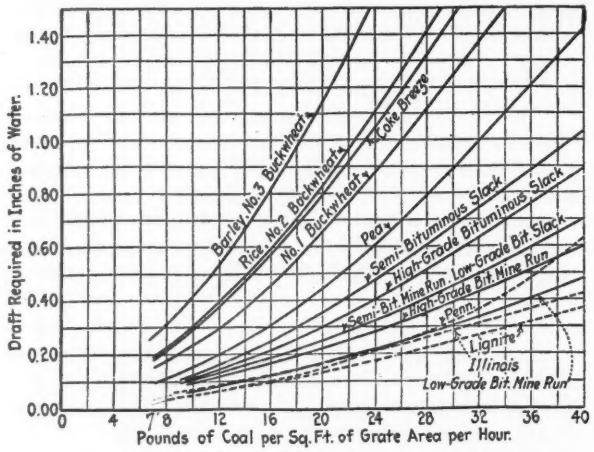


FIG. 1. APPROXIMATE FORCED-DRAFT PRESSURES REQUIRED FOR STOKERS

amounts proportionate to the volume of gases distilled from the coal. As the volume of gas distilled from different parts of the fuel bed decreases from front to rear, zone boxes are frequently provided, in the case of forced draft, so that the air pressure in each of these zones for the under-fire air may be regulated according to the rate of distillation.

Improvement in combustion, as shown by lower CO and higher CO_2 in the charts, Figs. 2 and 3, was accomplished by the introduction of over-fire air as shown in Fig. 3. It will be noted, as shown in Fig. 2, that the overfire air is directed to that section of the grate from which the highest percentage of CO is produced. Typical arrangement of zone boxes is also shown. A common plenum chamber serves all zone boxes, with the plenum box air supply controlled by means of a damper. Proper distribution of air for combustion, not total amount of air, is regulated by this arrangement, hence the excess air required for combustion is reduced to a minimum and combustion conditions are decidedly improved as shown by the higher percentage of CO_2 produced.

Mixing Methods

Adequate mixing of the combustible gases and air has long been known to be one of the prime requisites of proper combustion. Only since the advent of present high combustion rates, however, has this matter been given the thought it warrants.

Five forms of mixing are available. Steam jets have been used, but these devices are expensive to operate. Use of special firebrick structures in the furnace, such as deflector arches and wing walls, is satisfactory, except that cost of replacement is considerable where combustion rates are high. Introduction of furnace baffles has increased the CO_2 in the flue gases from 2 to 4 per cent. Furnace volumes have increased greatly during the past few years, which affords better opportunity for mixture but high velocities have increased the need for better mixture, hence use of impinging over-fire air streams.

Over-fire air is admitted, in practice, at the front, sides or bridge wall of the furnace. The latter, acting counter to the gas flow, avoids stratification experienced with the former method unless the air streams directed

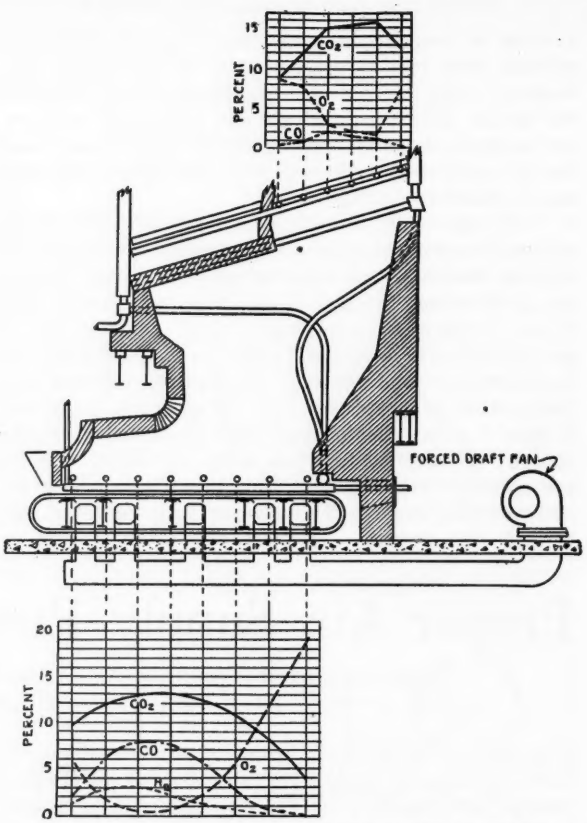


FIG. 2. TYPICAL COMBUSTION CONDITIONS EXISTING WITHOUT OVERFIRE AIR INJECTION

from the front of the furnace have an impinging effect. Besides causing turbulence, the air should be so admitted as to burn properly the CO distilled from the various parts of the fire bed as indicated in Figs. 2 and 3.

In the case of pulverized coal furnaces, tangential or cross fired nozzles were used to effect turbulence. In the latter case, one nozzle directed the pulverized coal downward in the furnace across the horizontal stream from a second nozzle. In the former case, some furnaces were constructed square while others were circular. Turbulent burners, which admit the pulverized fuel in such an intense swirl that it is not projected directly across the furnace, have displaced the tangential and cross injection methods by accomplishing adequate mixture as well as overcoming the lack of availability of the furnace corners.

Mechanical Draft Systems

In large plants, the general practice is to remove the products of combustion from the boiler setting by natural or induced draft or a combination of the two, to reduce the pressure of the gases within the boiler setting below that of the atmosphere and discharge them into the stack under positive pressure.

Centrifugal Fan Types

Centrifugal fans of the following types are usually employed for forced or induced draft systems: Steel plate, multiblade, conoidal, radial flow and cindervane. The housings of all these types are usually spiral in

cross section so as to permit the fluid to be carried away from the periphery of the fan wheel with as little disturbance and power loss as possible.

Steel plate fans consist of one or two spiders, each having 6 to 12 arms. Each arm or pair of arms carries a steel blade of considerable length, the blades being straight or curved either forward or backward depending upon the operating characteristics desired. The blade curvature has a marked influence upon performance, as shown in Fig. 4.

Multiblade fans are built up of two or more annular rings with many narrow curved blades inserted between them. These blades may also be curved forward or backward. Multiblade fans designed for high speed and pressure are reënforced by a number of annular rings and the wheels are relatively narrow, two such wheels being sometimes mounted in a common housing. Wheels of this type give high volumetric efficiencies and have a wide range of capacity at constant speed with small change in power requirements.

Conoidal fans are essentially of the multiblade type, but the blades are in the form of the surfaces of two tangent cones which gives the blade a forward curve at its inner edge and a considerable backward curvature at the periphery. This type combines desirable operating characteristics with a blade construction that is sufficiently rigid without stiffening rings.

Radial-flow fans have many blades with backward curvature so constructed that the air leaves the blades quietly with a minimum of shock losses. This type operates with a characteristic that shows a decrease in power required with increase in capacity after a maximum power requirement has been reached.

Special Provisions Required for Induced Draft

Fans of the conoidal, radial flow and backward-curved multiblade types are high-speed machines suitable for direct connection to either steam turbines or electric motors. Any of the foregoing classes of fans, when used to produce induced draft or forced draft with preheated air, are often equipped with water-cooled bearings, because of the high temperatures of the gases or air handled. Induced-draft fans of all types should be of rugged construction as they are subject to corrosive action of the flue gases and to abrasion of ash and cinder particles.

Cindervane fans are used, in induced-draft systems, where the gas velocity is very high and where considerable quantities of ash and cinder materials are likely to be discharged with the flue gases. Separation of the cinder particles is accomplished by sudden change of air direction and velocity, steel channels attached to the blades catching the cinders and directing them into chambers at the side of the casing. Approximately 10 per cent more power is required to operate a cindervane fan than is required for a fan of similar type without the eliminators.

Laws Governing Fan Performance

In operation, fans maintain a total pressure which is made up of two components, velocity pressure and static pressure either one of which may be zero under certain operating conditions. Velocity pressure creates and maintains the velocity of the fluid. Static pressure tends to burst housings or duct systems and is utilized to overcome frictional and other resistances to flow.

Fundamental laws governing performance of centrifugal fans may be expressed as follows: 1—The quantity of fluid discharged varies as the speed of rotation. 2—The pressure produced varies as the square of the speed. 3—The power required varies as the cube of the speed. 4—In a series of fans of the same type, having similar dimensions, same blade angles and rotating with the same blade-tip speeds under similar conditions of external resistance, the power required and the quantity of air discharged vary as the square of the linear dimensions.

Chimneys and Stacks

Brick, tile and concrete chimneys must be carefully built to prevent leakage due to poor bonding of ma-

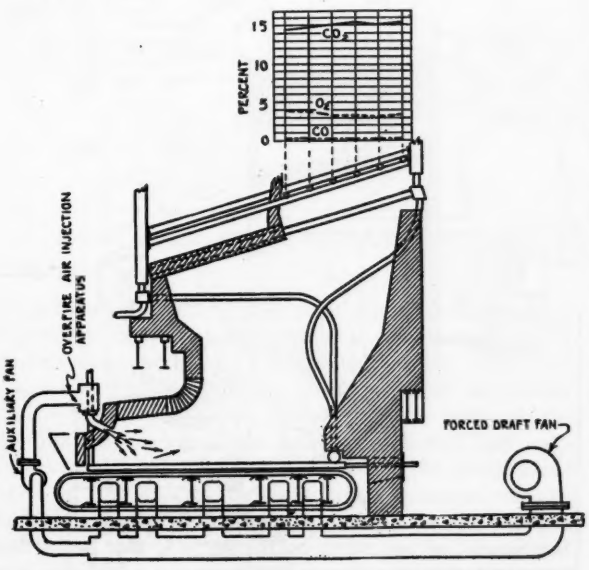
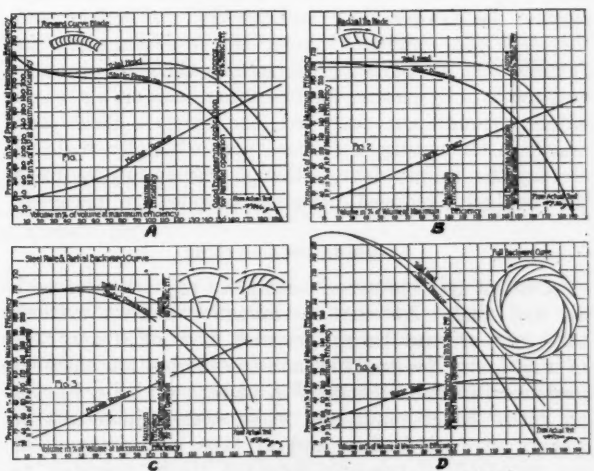


FIG. 3. TYPICAL COMBUSTION CONDITIONS EXISTING WITH OVERFIRE AIR INJECTION



TYPICAL PERFORMANCE OF CENTRIFUGAL FANS

FIG. 4. TYPICAL PERFORMANCE OF CENTRIFUGAL FANS. A. FORWARD CURVE BLADE. B. RADIAL TIP BLADE. C. STEEL PLATE WITH PARTIAL BACKWARD CURVE. D. FULL BACKWARD CURVE

TABLE SHOWING AVAILABLE DRAFT CALCULATED FOR 100-FT. STACK OF DIFFERENT DIAMETERS ASSUMING STACK TEMPERATURES OF 500 DEG. F. AND 100 LB. OF GAS PER HP. FOR OTHER HEIGHTS OF STACK, MULTIPLY DRAFT BY HEIGHT AND DIVIDE BY 100

Horse Power	DIAMETER OF STACK IN INCHES														Horse power	DIAMETER OF STACK IN INCHES						
	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120		90	96	102	108	114	120	132	144
100	.64															2600	.47	.53	.56	.59	.61	.62	.64	.65
200	.55	.62														2700	.45	.52	.55	.58	.60	.62	.64	.65
300	.41	.55	.61													2800	.44	.50	.55	.58	.60	.61	.64	.65
400	.21	.46	.56	.61												2900	.42	.49	.54	.57	.59	.61	.63	.65
500		.34	.50	.57	.61											3000	.40	.48	.53	.56	.59	.61	.63	.64
600		.19	.42	.53	.58											3100	.38	.47	.52	.56	.58	.60	.63	.64
700			.34	.48	.56	.60	.63									3200		.46	.51	.55	.57	.60	.63	.64
800			.23	.43	.52	.58	.61	.63								3300		.44	.50	.54	.57	.59	.62	.64
900				.38	.49	.56	.60	.62	.64							3400		.42	.49	.53	.56	.59	.62	.64
1000				.29	.45	.53	.58	.61	.63	.64						3500		.40	.48	.52	.55	.58	.62	.64
1100					.40	.50	.56	.60	.62	.63	.64					3600			.47	.52	.55	.58	.61	.63
1200					.35	.47	.54	.58	.61	.63	.64	.65				3700			.45	.51	.53	.57	.61	.63
1300					.29	.44	.52	.57	.60	.62	.63	.64	.65			3800			.44	.50	.52	.57	.61	.63
1400						.40	.49	.55	.59	.61	.63	.64	.65	.65		3900			.43	.49	.50	.56	.60	.63
1500						.36	.47	.53	.58	.60	.62	.63	.64	.65	.61	4000			.42	.48	.49	.55	.60	.62
1600						.31	.43	.52	.56	.59	.62	.63	.64	.65	.65	4100			.40	.47	.48	.55	.59	.62
1700							.41	.50	.55	.58	.61	.62	.64	.64	.65	4200			.39	.46	.51	.55	.59	.62
1800							.37	.47	.54	.57	.60	.62	.63	.64	.65	4300				.46	.50	.54	.59	.62
1900							.34	.45	.52	.56	.59	.61	.63	.64	.64	4400				.45	.49	.53	.58	.62
2000								.43	.50	.55	.59	.61	.62	.63	.64	4500				.43	.49	.53	.58	.61
2100								.40	.49	.54	.58	.60	.62	.63	.64	4600				.43	.48	.52	.58	.61
2200								.38	.47	.53	.57	.59	.61	.62	.64	4700				.41	.47	.51	.57	.61
2300								.35	.45	.52	.56	.58	.61	.62	.63	4800				.40	.46	.51	.57	.60
2400								.32	.43	.50	.55	.58	.60	.62	.63						.45	.50	.57	.60
2500									.41	.49	.54	.57	.60	.61	.63	5000					.44	.49	.56	.59

For other stack temperatures add or deduct before multiplying by height ÷ 100 as follows:

For 750 Degrees F. Add .17 Inch. For 700 Degrees F. Add .14 Inch.	For 650 Degrees F. Add .11 Inch. For 600 Degrees F. Add .08 Inch.	For 550 Degrees F. Add .04 Inch. For 450 Degrees F. Deduct .04 Inch.	For 400 Degrees F. Deduct .09 Inch. For 350 Degrees F. Deduct .14 Inch.

terials or cracks. Steel stacks, unless kept well painted, are subject to corrosive action of air. Unlined steel stacks are also corroded by constituents of the flue gases, so that the probable life of an unlined stack is less than that of a chimney.

Since opening of seams or of holes in steel stacks will permit air leakage and reduce draft, corrosion should be prevented, stacks be well guyed to prevent strain on seams and seams gone over and calked occasionally. Up to 50 ft. height, one set of three or four guy wires will be sufficient. For over 50 ft., two sets of guys should be used.

Stream line stacks have a venturi shape with a larger diameter at the top than at the throat, producing a lower resistance at the top than at the bottom, hence setting up an increased suction effect due to the ejector action and effecting a saving in the required power to handle the gases.

Draft Control

Draft control by means of ash-pit door regulation is poor. It shuts off the air supply through the fuel bed; the ash on the grates and the grate bars become heated and clinker and warped grates result. Although closing the ash-pit door reduces the air supply and therefore the combustion rate, air is drawn into the furnace and all parts of the setting through openings and cracks. By closing the breeching damper, air which enters through the fuel bed, the furnace doors and cracks in the setting, is reduced proportionally while by closing the ashpit door, although the supply through the fuel bed is reduced, the other supplies are increased.

Combustion Control

Control systems usually comprise regulation of both air and fuel. Automatic combustion control systems take into account boiler pressure, flow of steam, flow of air, rate of feeding fuel and the combustion chamber pressure in each furnace of a battery of boilers or of an entire boiler plant and make such adjustments of stokers of fuel feeders and of fans and dampers as are required to preserve constant steam pressure, to secure the desired division of load among the boilers, to insure the most favorable percentage of excess air or of CO_2 and to hold the most favorable furnace pressure.

Advantages of Automatic Control

Automatic combustion control has three principal advantages, namely, complete automatic operation with a minimum of supervision; uniform steam pressure in the delivery header and percentage of CO_2 in flue gases as high as is compatible with economical operation of the furnaces. Each fire bed receives only its allotted air supply regardless of whether the bed is thick or thin, of whether one or several fires are fed from a common duct or served by a single fan or of whether draft is provided by one or more stacks. The quantity of air supplied to burn each pound of fuel is by this method definite.

One type of combustion control system, shown diagrammatically in Fig. 5, measures the rate of flow of air or gases by the pressure drop or draft difference due to flow through a duct or a part of the boiler setting, while the speeds of stokers or fuel feeders are measured by centrifugal or electrical tachometers. The metered quantities are correlated through the medium of an electrical current, which can be subdivided as desired among several furnaces or boilers. Current acts in conjunction with the flow or speed metering devices to operate relays controlling electric motors which perform the actual regulation. The regulative actions are progressive, continuing until the desired balance between gas flow and fuel feed is obtained. Control is unaffected, therefore, by changes in resistance of gas passages, in thickness of fuel beds and in draft intensity produced by stacks, fuel and air being fed to each boiler according to a predetermined ratio and in response to load demand.

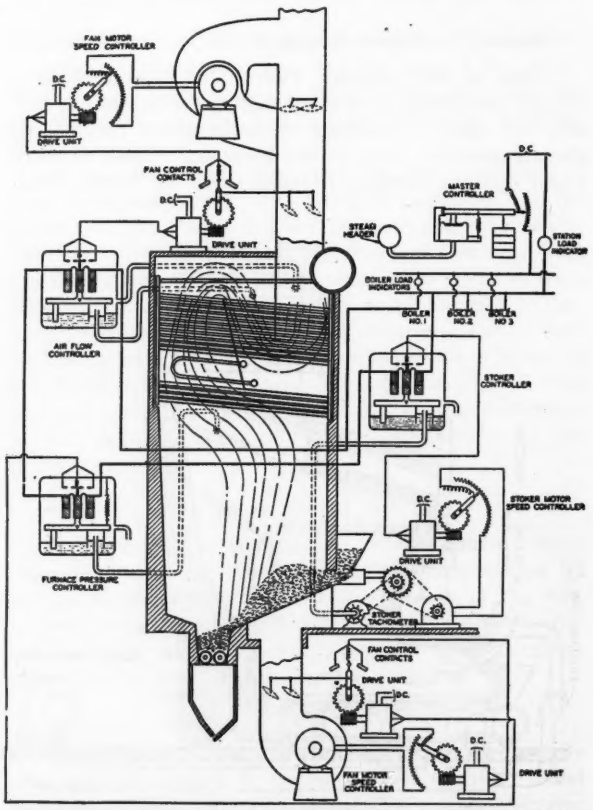


FIG. 5. COMBUSTION CONTROL SYSTEM FOR STOKER FIRED BOILER

In the illustration, the master controller will be seen to be connected to the steam header at a point such that the drop in pressure below standard boiler pressure is indicative of total boiler load. The master controller moves the rheostat arm in such a way that the current flow through the control system is proportional to the steam load, the control circuit being also regulated if desired by a master hand rheostat. The proportion of the control current distributed to each boiler is determined by the setting of an individual hand rheostat

Another combustion control system, shown in Fig. 6, regulates the supply of fuel and air through a steam-pressure-actuated master steam pressure contactor mounted on a master panel board. The relative proportions of fuel and air are modified automatically by the steam flow-air flow relation. Since with stoker-fired boilers it may be desirable to carry a higher excess air at low ratings than at high, arrangements are made for varying this air automatically with the rating as shown in Fig. 7. The control drives of this system are

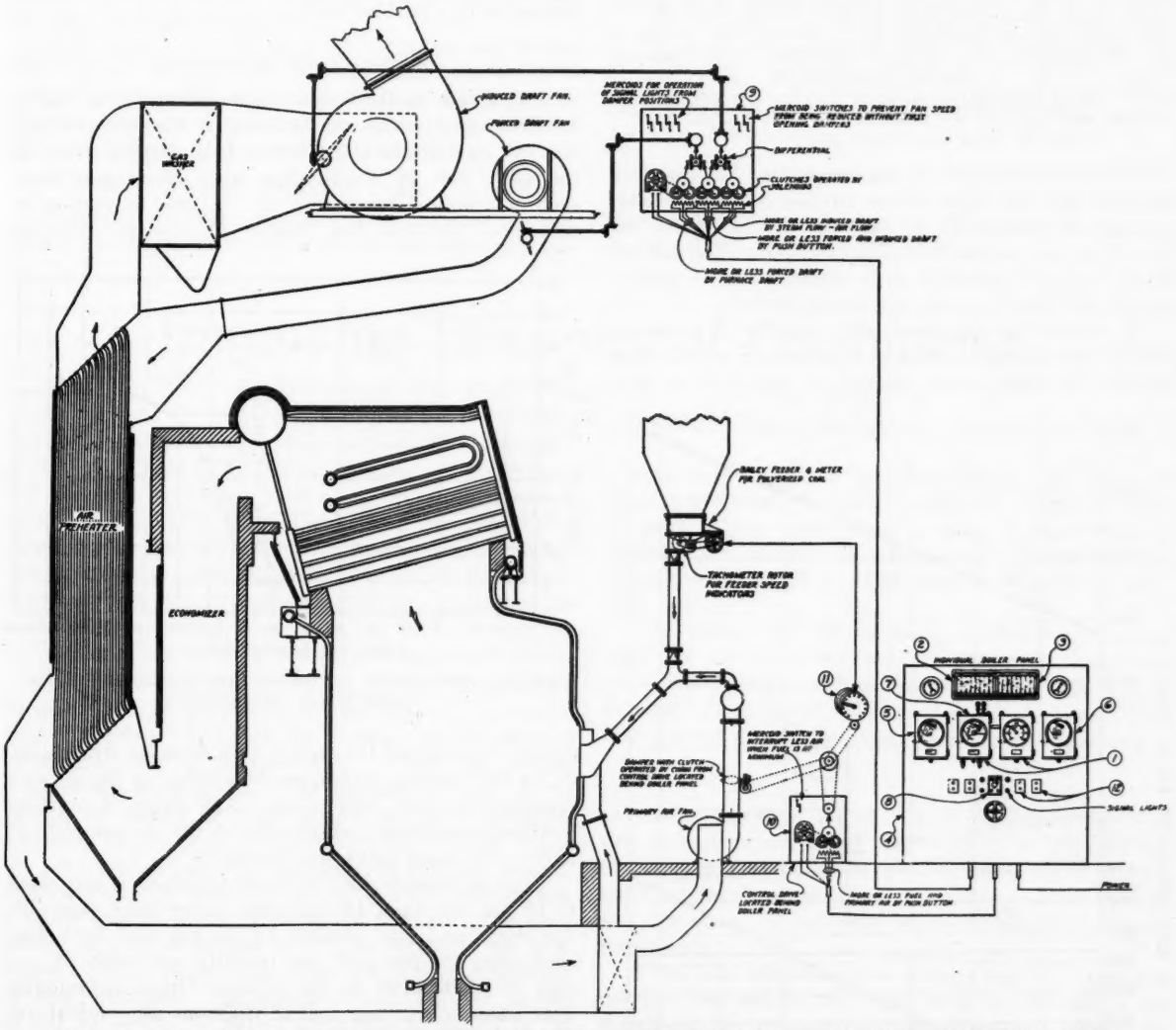


FIG. 6. DIAGRAMMATIC REPRESENTATION OF COMBUSTION SYSTEM AT THE CALUMET STATION OF THE COMMONWEALTH EDISON CO.

in each boiler circuit, this rheostat also affording manual control of the combustion rate at the corresponding boiler, when operating on individual control. The total station load is indicated by an ammeter in the circuit of the master controller, while the loads borne by individual boilers are shown by separate boiler load indicators on the individual boiler boards. The motor-drive units of the several controls, upon occasion, can be brought into operation by push-buttons on the individual boiler boards or the drive units can be disengaged and the dampers and motor-speed controllers operated directly by hand.

also provided with hand wheels so that the regulating devices for controlling the air and fuel supply can be operated by hand in case of emergency. The control drives which operate the regulating devices are the equivalent of reversing pilot motors but they have the motors running continuously to insure reliability.

Safety Attachments Prevent Faulty Action

Safety features are also provided so that, if the dampers are opened wide and the fans are running at their highest speed, an interlock prevents any additional fuel being supplied. Likewise, when the fuel

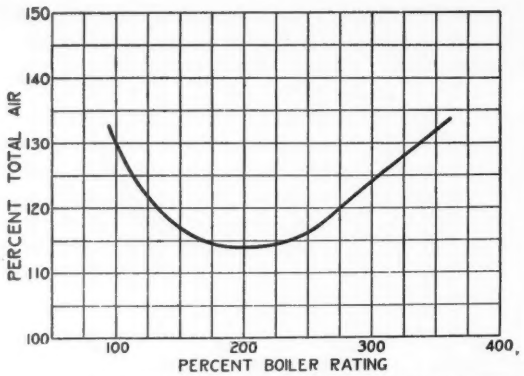


FIG. 7. CHART SHOWING HOW QUANTITY OF EXCESS AIR MAY BE VARIED AUTOMATICALLY WITH RATING

supply has been reduced to its lowest limit, an interlock prevents the air from being further reduced. This prevents the possibility of running with a serious deficiency of air at the extremes of travel. The control drives are also provided with travel limits to protect against overtravel of the regulating devices.

In another system, combustion regulation is accomplished individually as well as by a master regulator as follows: Overfire draft regulators, attached to each boiler, control the uptake dampers, holding a constant over-fire pressure in each case while a master regulator, which functions by the steam pressure, controls the combustion for the entire plant. This master regulator operates a main jack shaft to which chronometer valves in the steam line to the turbine blowers, are connected through a special disengaging device which allows the apparatus to be cut off automatically and placed on hand control merely by pulling a spring loaded pin out of engagement. A special disengaging device of this kind is located at the side of each boiler on each line connected to a turbine blower.

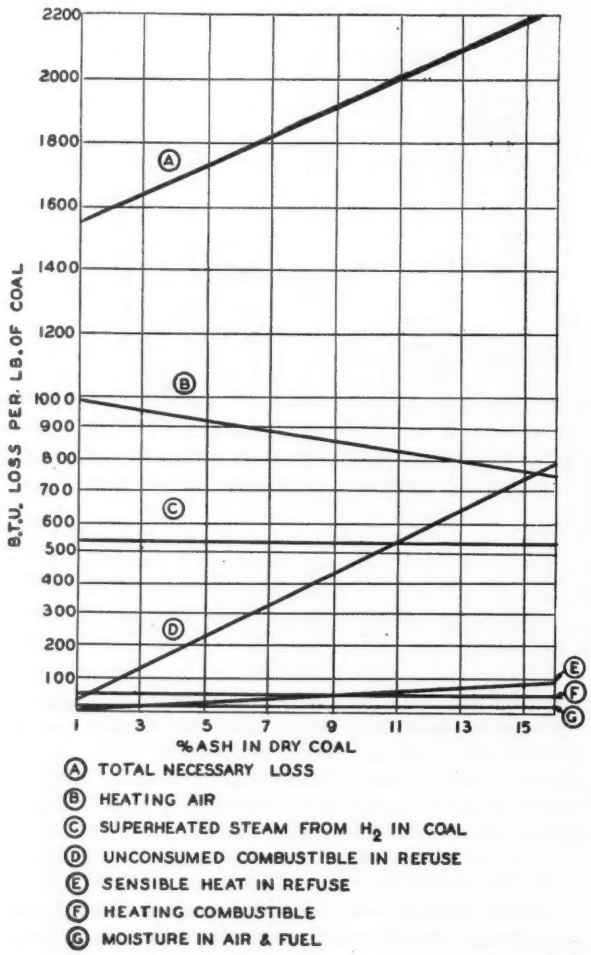


FIG. 8. RELATION BETWEEN NECESSARY HEAT LOSSES AND PER CENT OF ASH IN COAL

Losses Due to Excess Ash

Excess ash in fuel causes losses in fire beds due to air flow retardation and localization through the bed, delayed combustion and sensible heat carried away by the ash. Ash, in combination with other ingredients such as sulphur, forms clinker. Clinker formation or caking of the fuel bed results in localized burning around the edge of the clinker thus forming weak spots in the bed, causing improper distribution of the air and resulting in poor combustion. Any delay in starting combustion seriously affects the ability to complete it before the gases leave the furnace.

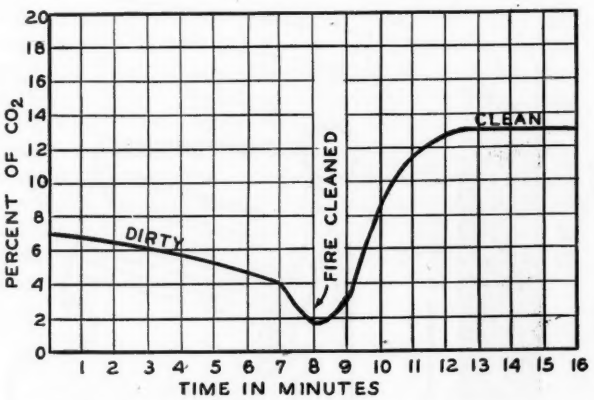


FIG. 9. EFFECT OF PROPER FIREBED CLEANING ON COMBUSTION EFFICIENCY

Loss of sensible heat in furnace refuse is estimated to be not less than 1.5 per cent under most favorable conditions and may amount to 4.5 per cent with fuel containing 25 per cent ash initially and with 35 per cent of combustible in the refuse. Other unavoidable heat losses in burning coal of different ash content are shown in Fig. 8.

Cleaning Firebed Increases Combustion Efficiency

Effect of properly cleaning a fire bed is illustrated by the increase in CO_2 shown in Fig. 9. Careless hand cleaning causes large inrushes of cold air which quickly cool the boiler and setting, destroy efficient combustion and, in time, work serious injury to the boiler because of the sudden and excessive changes in temperature. If the coal contains much ash or ash or that is readily fusible, the fires have to be cleaned often; if light fires are carried, less clinker is formed and less cleaning is necessary. Cleaning of fires should be thorough; all

clinker and ash should be removed so as to prevent fusion to the furnace walls, as large accumulations of clinker and adhesion to the furnace walls interfere with the operation of the furnace. When ash and clinker have accumulated to the extent of darkening the ashpit, cleaning of the furnace should be attended to at once.

Causes of clinker formation due to operation of the fire are: too thick fire bed, turning up of ash into fire when slicing, thin spots in fire, regulating draft by ashpit doors, excessively hot ashpit from coal burning in ashpit or preheated air.

Side to side cleaning is to be preferred and, if the front-to-rear method must be used while the boiler is under load, the side method of cleaning should be employed after the day's run so as to prevent large accumulations of clinker at the bridgewall.

Loss of Unburned Fuel

Tendency to leave a high-carbon content in ash occurs when fires are forced in order to produce a maximum percentage of CO_2, which, in many cases, limits the economical value of CO_2 to 15 per cent.

Other causes of unconsumed combustible in the refuse, as listed by Wickes Boiler Co. are: Coal unsuited to grate and furnace; too large openings in grate; high ash content fusing at low temperature forming clinker; too high furnace temperature, fusing ash to clinker; too frequent cleaning fires due to clinker; too frequent shaking of grates; too frequent dumping of grates or dump plates of stokers; too frequent poking, raking, hoeing and slicing; firing green coal onto bare spots of grate; carelessness in stoking and uneven fuel bed; too high rate of combustion for available draft; grate or stoker poorly proportioned to rate of combustion, draft and kind of coal and too small a furnace volume for rate of combustion, draft and kind of coal.

Graphical determinations of heat losses due to carbon in boiler refuse were presented on page 1102 of the Oct. 15, 1929 issue of Power Plant Engineering, also on page 1227 of the Nov. 15, 1929 issue.

Improving Efficiency of Combustion

Requirements for Good Combustion. Reducing Losses by Control of Air Supply. CO_2 Measurements. Use of Pyrometer

COMBUSTION OCCURS in the furnace by virtue of the chemical affinity that exists between the carbon in the fuel and oxygen. Combustion is primarily a chemical reaction between these two elements. When air is passed through a uniform bed of burning coal, the oxygen in the air combines with the carbon in the coal to form carbon dioxide, (CO_2) or carbon monoxide, (CO) depending upon the amount of oxygen available.

In a boiler furnace, where the object is to generate as much heat as possible from the fuel, it is necessary that the carbon unite with the greatest possible amount of oxygen, that is, to form CO_2. When this occurs, combustion is complete. The combustion of 1 lb. of carbon by means of pure oxygen to carbon dioxide, generates 3⅔ lb. of gas and liberates 14,544 B.t.u. Since the air contains only approximately 21 per cent oxygen, it is obvious that when air is used to effect combustion, a much greater quantity of gas is formed. The combusion of 1 lb. of carbon to CO_2 by means of air generates 12.52 lb. of gas, the excess over 3⅔ lb. consisting of inert nitrogen. The combustion of 1 lb. of carbon to CO by means of pure oxygen generates 2⅓ lb. of gas and liberates only 4351 B.t.u. or less than one-third of the heat liberated by combustion to CO_2.

It is evident, then, that in order to reduce the losses in the furnace, it is necessary to have as high a CO_2 content in the gases as possible, at the same time keeping the air supply close to the theoretical amount required. Practically, it is impossible to keep the air supply down to the theoretical amount. Due to imperfect mixture of the gases, if every particle of fuel is to have sufficient air for combustion, some particles will have more than the theoretical amount. It is necessary, therefore, to supply a certain amount of air in excess of the amount theoretically required to burn the fuel to CO_2. Complete combustion of the coal in a boiler furnace can be obtained usually with not more than 40 per cent excess air. Since this excess air plays no part in the combustion process, it merely passes through the furnace and is heated. Naturally, this constitutes a heat loss which must be kept to a minimum.

The amount of loss incurred in this way depends upon the nature of the fuel, the type and proportions of boiler, furnace and setting and upon the rate of driving. It is usually the greatest of all losses. The heat carried away may be expressed by the equation

$$h = w\ (t_e - t)\ C$$

in which, h = B.t.u. lost per lb. of fuel; w = weight of dry chimney gases per lb. of fuel; t_e = temperature of escaping gases, deg. F.; t = temperature of the air entering the furnace; C = the mean specific heat of the dry gases. (This may be taken as 0.24 for most purposes.)

From this equation, it is evident that this heat loss may be reduced in two ways: first, by decreasing the weight of the products of combustion and second, by reducing the temperature difference between the air entering the furnace and the flue gas leaving the boiler.

Reduction of the first loss is effected by reducing the amount of excess air. As stated above, the excess air should be kept below 40 per cent, but the exact amount will vary with the type and size of furnace, the fuel, etc. With gaseous, liquid and powdered fuels, the excess air may be kept within 10 to 20 per cent.

The temperature difference between the air entering the furnace and the flue gas leaving the boiler may be reduced either by preheating the air entering the furnace or by reducing the stack temperature or both.

At the temperature existing in the fuel bed or at the burners of a pulverized coal or oil fired furnace,

the combustion of oxygen and carbon takes place as fast as the oxygen can be supplied; that is, the oxygen and carbon combine as fast as they can be brought into contact. The velocity of the chemical reaction is very much higher than the rate at which the two reacting elements can be brought together, so that the rate of combustion depends solely on the rate of bringing the two elements together.

Before combustion can take place, however, it is necessary that the combustible first be raised to the kindling temperature. This varies for different fuels, the following being representative for fuels ordinarily used in power plant furnaces:

Lignite dust	300 deg. F.
Bituminous coal	660 deg. F.
Anthracite coal	750 deg. F.
Coke	800 deg. F.
Carbon monoxide (CO)	1200 deg. F.

These are the minimum temperatures at which these fuels will ignite. Usually it is necessary to have temperatures considerably higher than this in boiler furnaces. Combustion takes place more rapidly at higher temperatures, and is more nearly completed in the furnace.

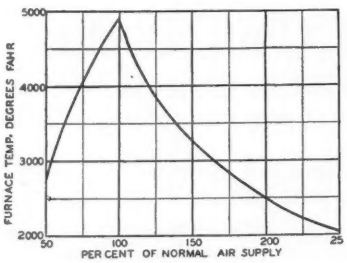


FIG. 1. CURVE SHOWING VARIATION OF COMBUSTION TEMPERATURE WITH AIR SUPPLY

The furnace temperature depends upon a number of things, but it bears a direct relation to the air supply as shown by Fig. 1. This curve is self-evident and requires no discussion. In order to maintain a high temperature at the point in the furnace where the fuel enters, that is at the point of ignition, various arrangements of arches and furnace brickwork have been designed to reflect heat onto the green fuel, acting substantially as a heat mirror. Such ignition arches receive heat from the rear or highly heated part of the fuel bed and furnace brickwork and radiate it to the point where the fresh fuel enters.

Assuming that by means of ignition arches and radiation from high temperature furnace parts, a sufficiently high ignition temperature can be obtained, the rate of combustion is dependent largely upon securing a rapid and proper mixture of oxygen and combustible. The actual time necessary, however, to effect proper combustion and to secure the desired rate of heat liberation varies widely in accordance with a number of factors. Combustion is a collective term having reference to thermo-physical, thermo-chemical and thermodynamic events which occur partly in parallel and partly in series and which in their relative course and in their natural velocities are subject to great variation.

When coal is burned on grates, the rate of combustion varies directly with the rate of passing air through the fuel bed; that is, it varies directly with the velocity of the air past the fuel. This also holds in the combustion of powdered coal. To get higher rates of combustion, it is necessary to get higher relative velocity between the coal particle and the air. Increasing the amount of air supply will accelerate combustion. A large excess of air, however, is a poor substitute for mixing and is undesirable as it increases the dry gas losses at a higher rate than it reduces the losses due to unburned carbon.

In the burning of pulverized coal, the rate of combustion depends upon the speed at which the air can be brought to the particles of carbon as they pass through the furnace. The actual time during which the coal remains in the furnace is very brief. Thus in the ordinary powdered coal furnace about 1 lb. of coal is burned per hr. per cu. ft. of effective combustion space, which means that a mean of about 13 lb. of gas is passing through each cu. ft. of combustion space per hr. If the mean temperature of the gas is considered to be 2100 deg. F., the corresponding mean volume of 1 lb. will be about 64 cu. ft. and the mean time taken by 13 lb. of gas per hr. to sweep through a cu. ft. will therefore be $\frac{1}{13} \times \frac{3600}{64} = 4.3$ sec. This is an average value.

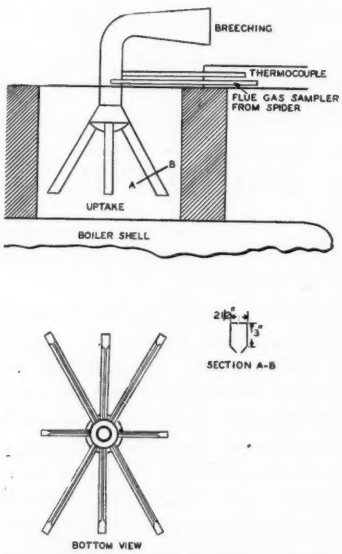


FIG. 2. SPIDER FOR SAMPLING FLUE GAS

In general, the time available for the oxygen and the coal particles to come into contact varies from 5 to 1.7 sec.[1] for rates of heat liberation of 10,000 to 30,000 B.t.u. per cu. ft. of combustion space per hour. This is about 100 times as long as the time available in a 6-in. fuel bed, where the time is only from 1/20 to 1/80 sec.

Testing

Principal among the various tests for determining combustion conditions in the furnace and distribution of the heat losses, is the flue gas analysis. For most

[1]Kreisinger and Cross.

purposes, it is necessary to take only the CO_2. This should be taken frequently while the conditions are being changed. For the gas analysis to have any value it is necessary that the sample taken be as nearly average as possible to obtain.

In making a gas analysis, the location of the sampling tube depends upon the use to be made of the analysis. If it is the total heat loss that must be determined, the sampler tube is placed in the uptake or smoke box. If the information is to be used in controlling the fire, the gas samples should be taken at some point before they are diluted by leakage through the setting.

For sampling furnace gases, the Bureau of Mines recommends a water-cooled tube or a quartz tube as preferable to a plain metal tube. An open ended tube placed in the center of the stream of gases gives, with water-tube boilers, results within 0.5 per cent of the average composition, if the setting is fairly tight. For more exact work, the sampler tube may terminate at the middle of a 1-in. iron pipe reaching across the uptake, closed at the ends and drilled on opposite sides with $\frac{1}{16}$-in. holes 6 in. apart. A "spider" by means of which a larger volume of gases is brought together at one point, is shown in Fig. 2. This also shows the location of the pyrometer thermocouple used in measuring the gas temperature.

Flue gas analysis is useful only if the knowledge gained by it can be applied to improving operating practice. For most purposes, the CO_2 indication will suffice but where greater refinement is desired after the CO_2 has been brought up to the required per cent, the CO determination can be made.

Although high CO_2 indicates a small amount of excess air, it does not necessarily means correspondingly good combustion. One per cent of CO in the flue gas would be a negligible indication of the quantity of excess air, but might mean 4½ per cent loss due to incomplete combustion. Low CO_2 may be caused by excess air, insufficient air (high CO) or improper mixture of the air and gases, but a surplus of air is the cause in almost every instance. The difference between the CO_2 percentages in the last and the first passes indicates the air leakage in the setting. CO_2 is also affected by the character of the fuel. The more hydrogen in the fuel, the less CO_2 in the flue gases. With an all carbon fuel, the CO_2 would be 21 per cent.

A valuable indication of the amount of heat loss in the furnace is the temperature of the flue gases where they leave the boiler. This can be taken by means of mercurial thermometers or by means of pyrometers, utilizing a thermocouple. A continuous record of flue gas temperatures is quite advantageous and can be obtained by using recording potentiometers. In taking the flue gas temperature, care should be exercised to secure the average, and to protect the thermometer by petticoats from radiation. The temperature should be taken at the same point as the gas sample.

Stopping Heat Loss Through Boiler Walls

LOSSES THROUGH DIFFERENT TYPES OF SOLID, AIR-COOLED AND WATER-COOLED WALLS AND METHODS OF STOPPING THEM WITH INSULATION

FURNACE WALLS used with modern boilers divide themselves into three general classes: solid walls, air-cooled walls and water-cooled walls. Four types of walls are shown diagrammatically in Fig. 1. These are to be considered types, not actual construction, as in practice the details of different walls will vary. The water-cooled wall does not show the refractories that may be on or around, between or behind the water tube. So far as the insulation is concerned, however, the general principles governing its application to the various types of water-cooled walls are similar in most cases.

CONSTRUCTION OF WATER-COOLED WALLS

In addition to the water tubes, the water-cooled wall may consist of refractories clamped or shrunk on the tube. Cast-iron blocks, plain or with refractory set in their faces are sometimes used. In some cases, the space behind, around and between these blocks and the tubes is packed with a material of high heat conductivity to increase heat flow to the water tube. In other cases, the wall consists of a special construction of metal blocks shrunk on the tubes to give a firm and uniform wall surface in the furnace. In still other cases, various forms of refractories are fitted around the tubes. Sometimes the bare tubes are embedded halfway in refractory brick work. At any rate, these refractories serve to protect the insulation from the high temperatures that would otherwise penetrate between the tubes. Then there is the insulation itself and finally an outside protective and air sealing finish, which may consist of asbestos wood, steel plate, plastic covering material or hard-finish insulating cement. Sometimes asbestos wood panels are used with steel battens gasketed to provide air-tightness.

HEAT LOSS THROUGH SOLID WALLS

Solid walls are of various combinations of fire brick, common brick and insulating brick construction, as shown in Fig. 2. The charts in this figure also show the heat loss through various combinations, demonstrating the saving due to insulating.

Solid walls may be covered with a protective and air-sealing finish of asbestos wood paneling or of hard-finish insulating cement. The veneer construction shown in Fig. 1B is adaptable to installation on existing settings as well as on new work, omitting the bonding courses and securing the veneer course to the existing wall by metal fastenings. To cover this, insulating cement may be applied over mesh reënforcement. For new walls where bonding courses may be used, types of insulating brick with durable and attractive finish are available.

SAVING HEAT WITH AIR-COOLED WALLS

Figure 1C is merely diagrammatic of the principles involved, since there are so many commercial designs

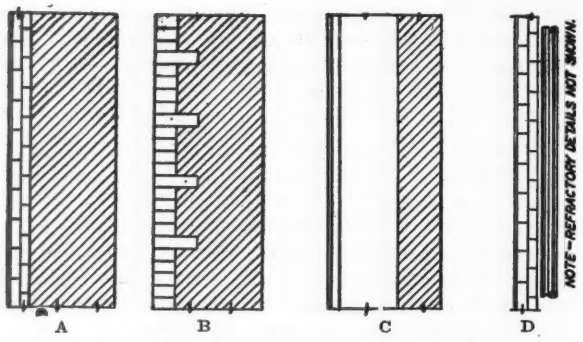


FIG. 1. TYPICAL FURNACE WALL CONSTRUCTIONS, DIAGRAMMATIC ONLY

A—Solid brick wall with block insulation and asbestos wood casing. B—Solid wall insulated with veneer course of insulating brick. C—Air-cooled wall, air space enclosed by insulation and asbestos wood casing. D—Water-cooled wall with block insulation and asbestos wood casing.

of air-cooled walls. Fundamentally, all furnace walls of this type consist of an inner refractory wall, space or spaces for circulating air and an outer insulating casing.

Value of Preheated Air Equals Value of Fuel Needed to Replace Its Effect

As in the case of air preheaters, many engineers consider that since the air is heated in preheaters or in air-cooled walls by heat that might otherwise be considered waste heat, as for example the heat in the flue gases or the heat radiated from the furnace walls, the cost of this heated air is insignificant. It actually does cost something, however, as at least the fixed charges on the equipment required to recover the heat must be charged against it. After all, says McMillan, it is the value of the heat and not its cost that is important.

This value depends on the extent to which the preheated air improves the entire process of steam generation. The preheated air is employed not only to recover waste heat but also to increase combustion efficiency and in the case of the air-cooled wall, to decrease maintenance of the furnace. On the whole, says McMillan, the value of the preheated air is equal to the cost of fuel required to replace its effect; that is, the cost of the additional fuel required to produce a given quantity of steam using air at lower temperature, over that required for the same production with air at the higher temperature.

The function of the insulation is, of course, to keep the heat in the air once it has been put there and to maintain its effectiveness by minimizing temperature drop in the air until it is admitted to the furnace.

Some installations of air-cooled furnaces are used with air preheaters and in such cases the function of the air duct is more to cool the furnace walls than to preheat the air. Several installations of air-cooled walls are found in which the air is introduced into the wall under pressure.

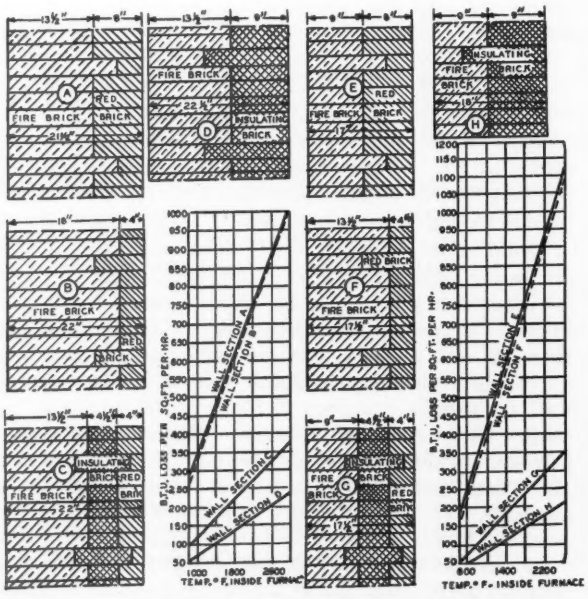


FIG. 2. HEAT LOSS THROUGH VARIOUS FURNACE WALLS SHOWING SAVINGS FROM INSULATING

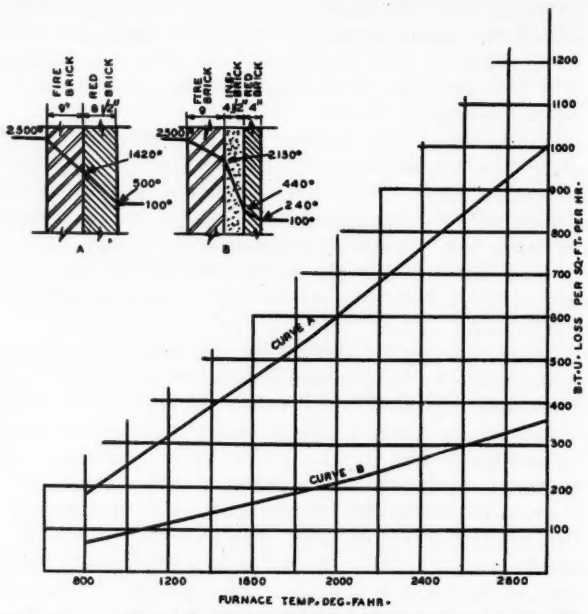


FIG. 3. HEAT LOSS FROM WALLS WITH AND WITHOUT INSULATING LINING

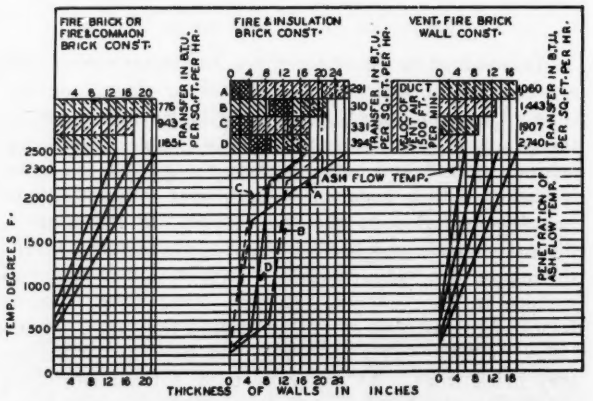

FIRE BRICK OR FIRE & COMMON BRICK CONST.
FIRE & INSULATION BRICK CONST.
VENT. FIRE BRICK WALL CONST.
HEAT TRANSFER IN B.T.U. PER SQ.FT. PER HR.
DUCT
ASH FLOW TEMP.
PENETRATION OF ASH FLOW TEMP.
TEMP. DEGREES F.
THICKNESS OF WALLS IN INCHES

FIG. 4. PENETRATION OF DANGEROUS TEMPERATURES AS INFLUENCED BY WALL CONSTRUCTION

Heat losses through various types of brick walls are shown in Fig. 2 as noted above. Other data on the heat losses are shown in Fig. 3, giving the loss and temperature gradients through solid and insulated walls. With 2500 deg. furnace temperature, the values are 800 B.t.u. per sq. ft. per hr. for the solid wall and 280 for the insulated. For 1000 sq. ft. of wall, the 520,000 B.t.u. saved per hr. represents 43 lb. of coal, 4.25 gal. oil or 867 cu. ft. of gas. Walls are tied together with ½-in. wire mesh or expanded metal lath every five or six coursers or with 9-in. firebrick headers staggered and spaced 18 in. longitudinally.

In Fig. 4, Ricketts shows calculated temperatures for three types of walls: all brick, brick with insulating center and brick with cooling air duct. In each case, the upper diagram represents combinations of firebrick, insulating brick with 0.1 the conductivity of firebrick, red brick and so on, the left-hand edge representing the outside while the lower lines give the temperature drop from 2500 deg. in the furnace. It is stated that there is great danger of ash erosion of the insulated walls, in which the ash flow temperature, 2300 deg., penetrates farther than in the solid or ventilated constructions. The latter are considered preferable wherever it is desirable to introduce considerable secondary air but not where all or most of the air is primary.

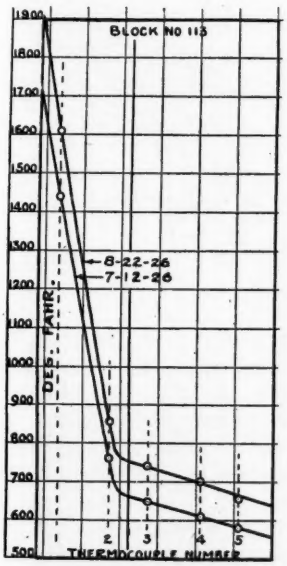


FIG. 5. TEMPERATURE GRADIENT THROUGH A REFRACTORY FACED WATER-WALL BLOCK

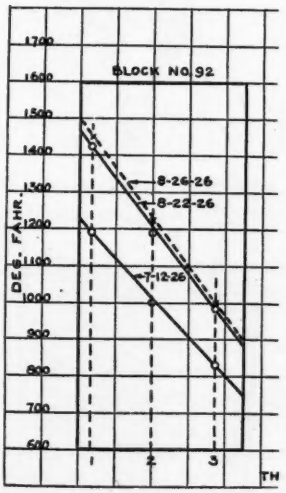


FIG. 6. TEMPERATURE GRADIENT THROUGH A PLAIN CAST-IRON WATER-WALL BLOCK

Frankenhoff, however, states that the ash-flow temperature penetration is only ⅛ in. greater for the insulated construction and the temperature at the back of the firebrick only 150 deg. higher.

As a result of tests at Long Beach Plant No. 2, temperature gradient curves were obtained on two types of water-cooled walls. One using refractory faced blocks, is shown in Fig. 5. The other for plain cast-iron blocks is shown in Fig. 6.

Total water wall surface was 936 sq. ft. per boiler, the side walls tubes covered with refractory faced iron blocks, and the front wall tubes recessed in special tile to expose about ¼ their surface to the furnace.

Walls were insulated on the outside by a composition plaster of slag-wool and asbestos about 3½ in. thick. Various types of seals were used to prevent air infiltration around the water walls. Side walls required no seal at the top, the tubes passing out between special tile. A pliable coat of sealing material on the outside made it tight. Bottom of the side walls, with movable headers to allow for expansion was sealed on the under side of the furnace floor by a seal of sheet spring steel fastened to the sheet iron of the furnace floor. This held rolled asbestos against the water wall blocks to allow a slight movement without opening up. In other cases, the spring steel was bolted to both stationary part and water wall, flexibility of the spring steel taking the expansion strain.

Heat Loss from Other Parts of Boilers and Settings

EXPOSED TOPS of boilers, says the Magnesia Association, are to be covered with blocks finished with ½ in. of plastic and coat of hard-finish cement. Covering is to be extended over surface of the brick setting on either side of and between boiler tops and drums and over the top of the combustion chamber. Ends of boiler drums, both heads and rings, are to be covered with blocks and plastic or all plastic securely wired in place, with smooth finishing coat and canvas jacket, beveled around manholes. Bottom 4 ft. of sidewalls is to be protected by a sheet-metal casing.

On connections from boiler to chimney, including portions running to economizer, ½-in.-mesh, black iron wire cloth is to be applied with ¾-in. V-iron attached to form air space and fastened directly to the iron, block and plastic being then applied. All hot and tem-

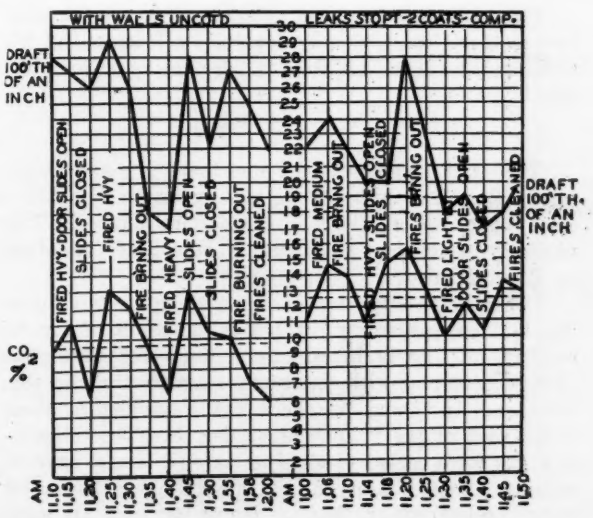


FIG. 1. EFFECT OF STOPPING AIR LEAKS BY PAINTING BOILER SETTING WITH COMPOUND

perate air and cold-air ducts and exposed surfaces of fan casings, tempering coils, etc., are to be covered with 1-in. blocks; if unconcealed, to be finished in sheathing paper and 8-oz. canvas jacket. Heaters, receivers, return tanks, traps, etc., to be covered with blocks and plastic depending on temperature.

Excess air entering boiler settings through defects in the settings causes combustion losses. Various compounds are available that can be painted on leaky brickwork. Figure 1 shows the effect of these. Smith suggests painting faulty brickwork with mortar of cement and fire clay, with ammonia added and painting the whole set-

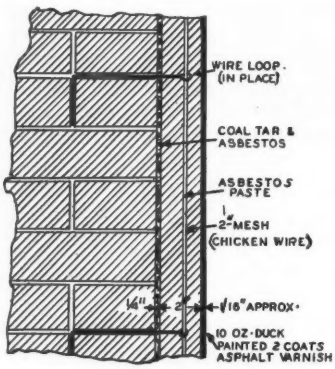


FIG. 2. ONE METHOD OF INSULATING A BOILER

ting with asphaltum-base paint. In one installation, this treatment raised CO_2 from 8.5 to 13 per cent. Hays recommends calking cracks in brickwork with a thin mixture of fire clay and pulled cotton waste. Many of the manufacturers of insulation have plastic materials for this purpose.

Figure 2 shows an insulating covering for a boiler setting that has given good results. On two 500-hp. boilers, cost of application was $400 and saving is estimated at $1000 a year.

FOR SOME CALCULATIONS, it is handy to use the absolute temperature commonly denoted by T instead of the ordinary or Fahrenheit scale t; the relation between the two is

$$T = t + 460$$

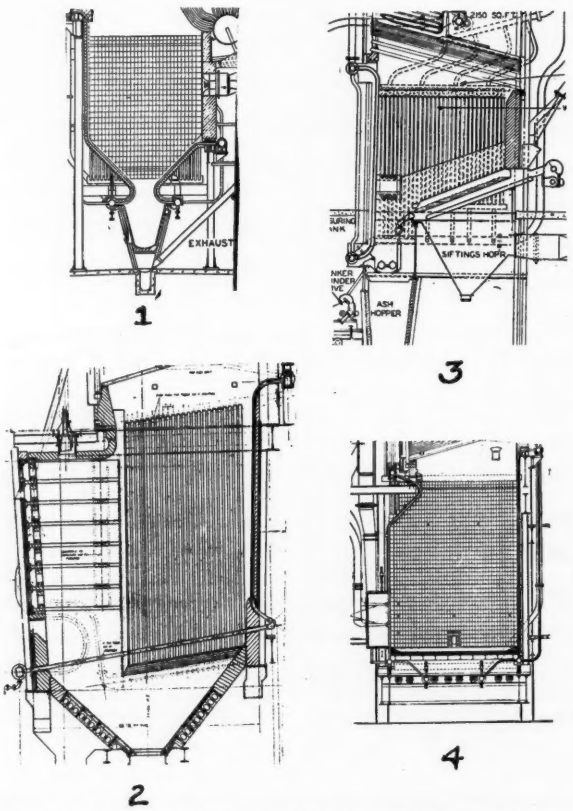
The exact value is 459.6 but there is some uncertainty about two units in the last figure, so that 460 is close enough for all practical engineering purposes. This places freezing point at 32 deg. F. or 492 deg. absolute, or T = 492 deg.

Contrary to what is sometimes thought, this figure was not selected arbitrarily but is the result of careful experiment. Early investigators discovered that gases change in volume with changes in temperature, and that the change in volume for one degree Fahrenheit is about 1/460 part of the volume at 32 deg. F. Theoretically, if a gas were cooled to absolute zero, it would have no volume. As a matter of fact, absolute zero has never been reached closer than a degree or two, all gases liquefying before that point is reached; also, the law does not hold true at extreme temperatures.

Furnace Bottoms

PRIMARY FUNCTION of construction used in the bottom of modern furnaces is to cool the ash below its fusing temperature so that it can be easily handled. The exception to this is the slag tap furnace, Fig. 4, in which the object is to keep the ash and slag in a molten state so that they can be drawn off through a tap hole.

With the hearth screen, Fig. 2, however, the water-cooled hopper bottom, Fig. 1, and the water-cooled back wall as used with stokers, Fig. 3, a secondary effect is to insulate the furnace bottom, thus preventing loss of



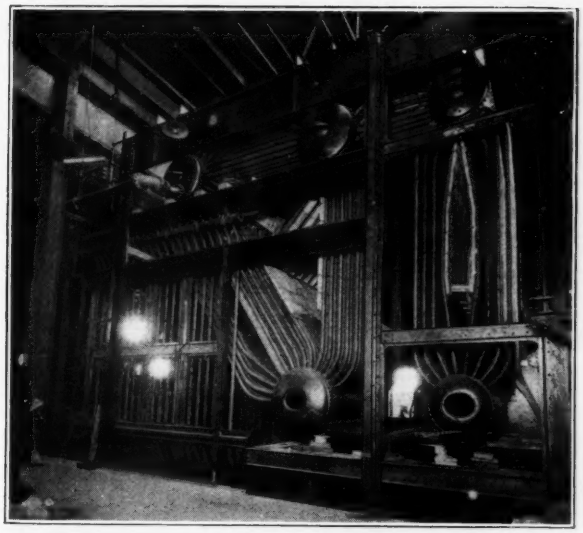
FIGS. 1-4. TYPES OF FURNACE BOTTOMS: 1, WATER-COOLED HOPPER BOTTOM; 2, HEARTH SCREEN BOTTOM; 3, WATER-COOLED WALLS WITH STOKER; 4, SLAG-TAP FURNACE

heat. At the same time, the heat given up by the ash, the fusion temperature of which is usually between 1900 and 2900 deg., is taken up by the water in the screen, this water circulating in the water-cooled walls and finally in the boiler proper.

Slag screens are often used also in the upper part of the furnace, as at Delray and other modern stations, to prevent fusion of ash and slag on the boiler tubes. Sometimes this is effected by a separate row of screen tubes and in other cases the lower boiler tubes are spaced widely apart for this purpose.

SAFETY VALVES should always be installed on an air or ammonia compressor between the compressor system and the discharge valve.

HEAT TRANSFER AND ABSORPTION



Clean Surfaces Are Best for Heat Transfer

MODES OF HEAT TRANSFER, PORTIONS OF BOILERS DESIGNED TO ABSORB HEAT, METHODS OF KEEPING CLEAN SURFACES

IN THE TRANSFER of heat from the furnace to the water and steam in a boiler, three modes are employed, i.e., radiation, convection and conduction.

Heat transferred by radiation goes directly from the fuel bed or incandescent particles in the gas to the boiler heating surface and does not appear as sensible heat in the gases. Radiant heat is that which comes to those portions of a boiler by virtue of direct exposure to the fuel bed or burning gases, i.e., the parts that are "in sight of" the incandescent section of the furnace. It may also come from heated portions of the furnace lining or arches whose temperature is above that of the absorbing surface.

Experiments would indicate that, at 2000 deg., radiant heat transmission is about 15 times as effective as that by convection and in boiler operation the most active surfaces are those exposed to radiant heat. The reason for this is probably due to the resistance offered to convection heat by the gas film next the heating surface through which radiant heat passes with little resistance.

HEAT TRANSFER BY CONVECTION

When heat is transferred by convection, it is carried from its source to the cooler body by means of the gas particles. These become heated by contact with the burning fuel and as they come in contact with the cooler boiler surface, they share the heat they have accumulated with the water in the boiler, thus the temperature of the gases is lowered as it passes through the boiler and that of the water raised to the point of evaporation, any further heat absorption going to supply the necessary latent heat and superheating the steam.

In a clean boiler, the principal resistance to heat transfer by convection is through the film of gas next the dry surface of the tube or plate. This is well illustrated by the diagram, Fig. 1, which indicates the rapid drop in temperature through the gas film as compared with the drop through the metal and the water film.

Transmission of heat by conduction takes place in a boiler as the heat passes from the particles of heated gas in contact with the soot coating into the soot and then through the metal and the scale into the particles of water next the scale.

STRAIGHT LINE LAW FOR BOILERS

By means of tests to determine the relation between the heat absorbed by water in a boiler and the heat available for absorption, Lucke and others have dem-

Formulas for heat transfer:

By radiation:
Expressed in B.t.u. per hr. per sq. ft. of surface, the radiation from a so-called black body at a temperature of T degrees F. absolute is very nearly

$$1600 \left\{ \frac{T}{1000} \right\}^4$$

By convection:
J. E. Bell writes the formula originally due to Osborne Reynolds as follows:

$H = (a + bw)(T - t)$

wherein H = heat units transferred per unit of tube surface per unit of time,
T = mean temperature of the fluid,
t = temperature of the tube wall,
a = constant, probably proportional to conductivity,
b = constant that is proportional to the specific heat, and also varies with the temperature in some way that so far seems obscure,
w = mass flow per unit area of the channel.

By conduction:
The quantity of heat transmitted through a unit, area of plate in a unit of time is related to the conductivity and to the difference in temperatures between the dry and wet surfaces of the plate as follows:

$$H = \frac{C}{D}(t_1 - t)$$ wherein

H = quantity of heat transmitted per sq. ft. of the heating plate in B.t.u. per hr.
C = coefficient of conductivity of 1 in. thickness of the substance between the dry and wet surfaces, in B.t.u. per deg. F. temperature difference per sq. ft.
D = distance between the two surfaces in in.
t_1 = temperature of the dry surface, in deg. F.
t = temperature of the wet surface, in deg. F.

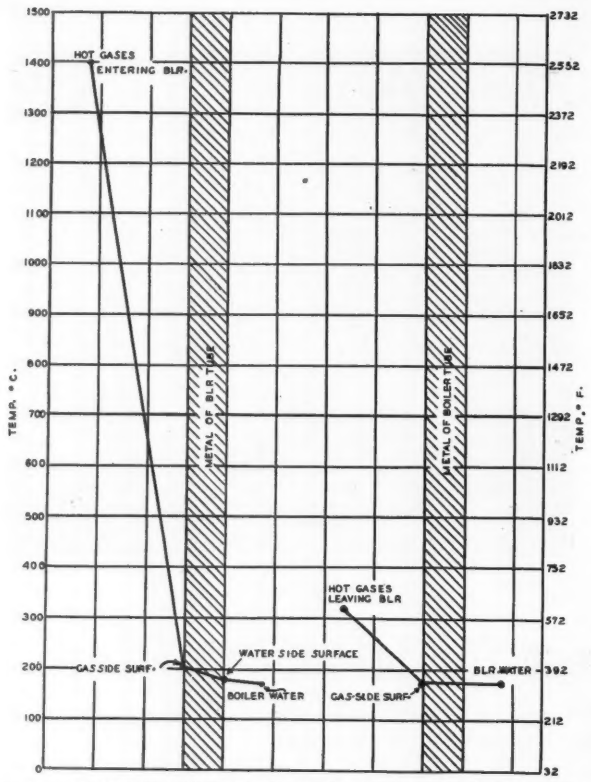


FIG. 1. TEMPERATURE DROP AS HEAT PASSES FROM THE HOT FURNACE GASES TO THE WATER IN THE BOILER

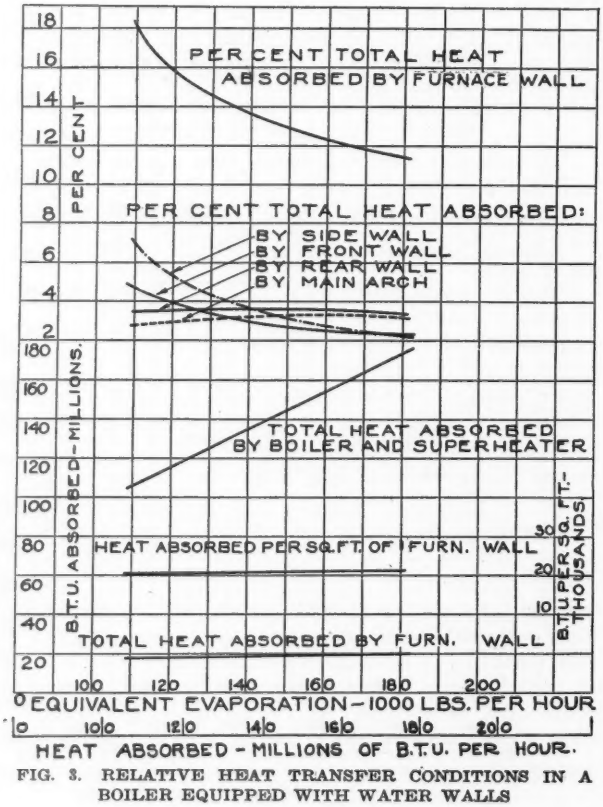

PER CENT TOTAL HEAT ABSORBED BY FURNACE WALL
PER CENT
PER CENT TOTAL HEAT ABSORBED:
BY SIDE WALL
BY FRONT WALL
BY REAR WALL
BY MAIN ARCH
TOTAL HEAT ABSORBED BY BOILER AND SUPERHEATER
B.T.U. ABSORBED - MILLIONS.
HEAT ABSORBED PER SQ.FT. OF FURN. WALL
TOTAL HEAT ABSORBED BY FURN. WALL
B.T.U. PER SQ. FT. - THOUSANDS
EQUIVALENT EVAPORATION - 1000 LBS. PER HOUR
HEAT ABSORBED - MILLIONS OF B.T.U. PER HOUR.

FIG. 3. RELATIVE HEAT TRANSFER CONDITIONS IN A BOILER EQUIPPED WITH WATER WALLS

onstrated that this relation becomes a straight line for a given boiler and furnace which has become known as the straight line law for boilers. It is pointed out that, as a general rule, a straight line will also result when the heat absorbed is plotted against the rate of combustion and that if a curve results from plotting these relations it is evident that a variable fractional furnace loss exists; that is, the per cent of heat lost in the furnace increases as the rate of combustion increases.

To take advantage of the most efficient methods of

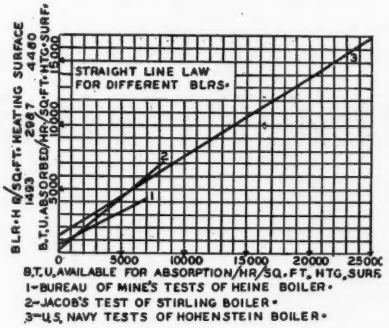

STRAIGHT LINE LAW FOR DIFFERENT BLRS.
B.T.U. ABSORBED/HR/SQ.FT. HTG. SURF.
B.T.U. AVAILABLE FOR ABSORPTION/HR/SQ.FT. HTG. SURF.
1-BUREAU OF MINE'S TESTS OF HEINE BOILER.
2-JACOB'S TEST OF STIRLING BOILER.
3-U.S. NAVY TESTS OF HOHENSTEIN BOILER.

FIG. 2. STRAIGHT LINE LAW FOR DIFFERENT BOILERS ILLUSTRATES THE RELATION BETWEEN THE HEAT ABSORBED AND THE HEAT AVAILABLE FOR ABSORPTION

heat transfer, various types and arrangements of boiler heating surfaces have been used and the Bureau of Mines has published the following statements relative to the comparative heat absorbing qualities of different surfaces:

"A boiler that has its heating plates arranged in such a way that the gas passages are long and of small cross-section is more efficient than one in which the gas passages are short and of large cross-section.

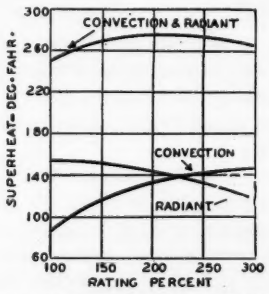


FIG. 4. PERFORMANCE CURVES OF RADIANT, CONVECTION AND COMBINATION SUPERHEATER ARRANGEMENT

"If the same weights of gas at the same initial temperature are passed through a 2-in. and a 4-in. flue, both flues having the same length, the 2-in. will absorb more heat than the 4-in. flue, although the 4-in. flue has twice as much heating surface as the 2-in.

"To increase the efficiency of water-tube boilers, insert baffles in such a way that the heating surfaces are arranged in series with reference to the gas flow, thus making the gas passages longer.

"In multi-tubular boilers, the efficiency increases as the diameter of the tubes decreases, and as the length of the flue increases. In water-tube boilers, it increases as the cross-section of the gas passages between individual tubes decreases, and as the length of the passages increases.

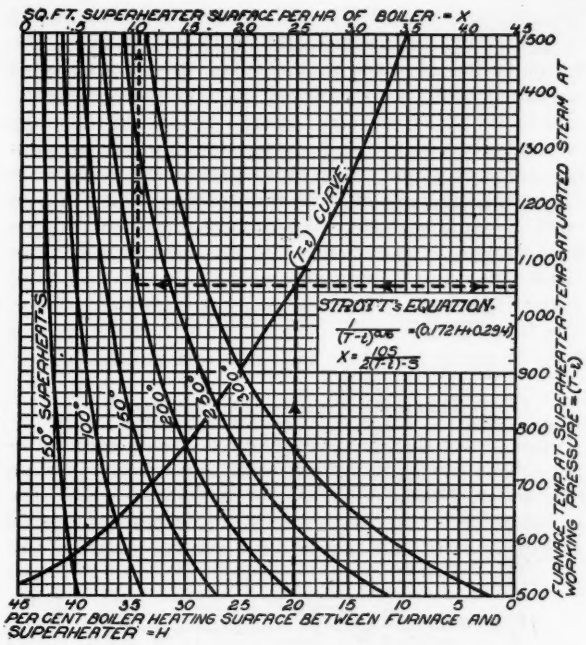

SQ. FT. SUPERHEATER SURFACE PER HR. OF BOILER = X
0 5 10 15 20 25 30 35 40 45
(T-t) CURVE
STROTT'S EQUATION.
(T-t)^1.25 = (0.172H+0.294)
X = 105 / 2(T-t)-3
50° SUPERHEAT
100°
150°
200°
250°
300°
FURNACE TEMP. AT SUPERHEATER-TEMP. SATURATED STEAM AT WORKING PRESSURE = (T-t)
1500 1400 1300 1200 1100 1000 900 800 700 600 500
45 40 35 30 25 20 15 10 5 0
PER CENT BOILER HEATING SURFACE BETWEEN FURNACE AND SUPERHEATER = H

FIG. 5. CHART FOR DETERMINING NECESSARY HEATING SURFACE FOR SUPERHEATERS

"As the velocity of the gases over a heating plate increases, the true boiler efficiency at first drops, and then, after the gases exceed a certain velocity, it remains nearly constant."

During recent years, considerable attention has been given to heating surfaces that take advantage of the radiant heat of the furnace. These surfaces are made up in the form of water walls, water arches, hearth screens and radiant superheaters, and vary greatly in their proportion to the regular boiler surface.

No standard of proportions has as yet been set but Fig. 3 illustrates modern heat transfer conditions as exemplified by unit No. 4, boiler No. 5 of the Crawford Avenue Station. Not only have these surfaces greatly increased the steaming capacity of boilers, increased the heat liberation per cubic foot of furnace volume and reduced furnace maintenance costs but along with their development has come higher efficiencies in boiler operation. For proper operation of a furnace, the temperature must never be below the ignition point of the fuel so the amount of heating surface exposed to the radiant heat of the furnace is limited by the minimum rate of combustion at which the boiler will operate.

In power plant practice, superheaters are nearly always designed as part of the boiler and located within the same setting. Convection type superheaters are located somewhere in the gas passage away from the radiant heat of the furnace. The most common location in water-tube boilers is in the space between the first and second passes of the boiler but with the increasing use of high-pressure and high-temperature steam, the superheater is placed in an interdeck location where the gases are at a higher temperature. With return tubular boilers, the location of the convection type superheater is almost invariably at the rear of the boiler in the return gas passage.

Radiant type superheaters are placed in such a location as to receive radiant heat from the furnace. This may be along any of the walls of the furnace or under the arch. As a rule, radiant type superheaters are used in series with convection type superheaters, as the combination gives a more nearly uniform temperature to the steam under varying loads.

Keeping Surfaces Clean

HEAT TRANSFER from the furnace to the water in the boiler may be greatly reduced by the accumulation of soot and slag on the gas side of the heating surface and scale on the water side. These conditions are changeable in every installation and need constant attention. The quality of fuel, rate of combustion and purity of boiler water are the principal factors affecting changes in the cleanliness of heating surfaces.

To keep the dry side of heating surfaces clean during the operation of boilers, engineers resort to the use of soot blowers and tube scrapers usually at regular stated intervals, though in some plants equipped with flue gas thermometers the operators are instructed to dust the tubes when the flue gas temperature reaches a stated maximum. As a rule, mechanical soot blowers are permanently located in the boiler settings with the elements and nozzles advantageously placed so as to cover with a jet of steam or air all sections of the heating surface. Supplementing these, hand lances are usually provided by means of which the soot may be blown from out-of-

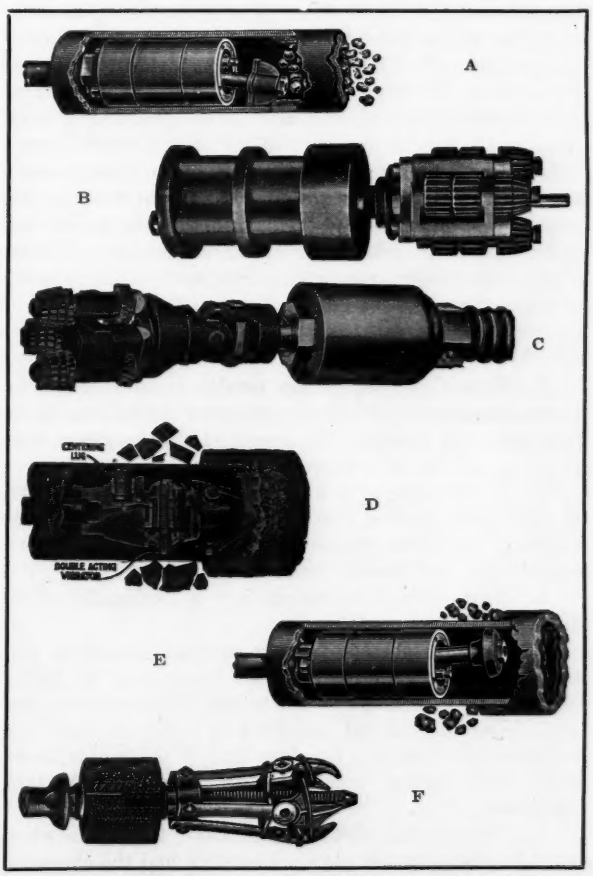


FIG. 1. DEVICES FOR CLEANING BOILER TUBES

A and B, cleaners for straight water tubes. C, one type of cleaner for bent water tube. D and E, two vibrating type scale removers for fire tube boilers. F, combination tube brush and scraper for fire tube boilers.

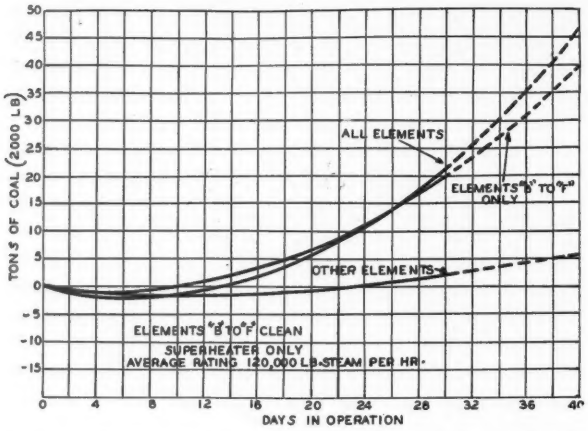


FIG. 2. CUMULATIVE NET SAVING DUE TO USE OF SOOT BLOWERS ON UNIT IN EDGAR STATION

the-way corners when the boilers are out of service or held in reserve. For return tubular boilers, standard design soot blowers should be installed and tube scrapers should also be used regularly as the dust dropping out of the gases of combustion is likely to become encrusted in the tubes.

Tests reported by the N.E.L.A. exemplify well the value of soot blowers in the operation of a boiler, the curve Fig. 2 being plotted as the result of these tests which were conducted on a horizontal water-tube boiler, installed in the Edgar Station, with a heating surface of 19,743 sq. ft. and operating at 375 lb. gage pressure. It is equipped with an interdeck superheater and an economizer, served by an underfeed stoker and operates with forced and induced draft. The curves show that it takes 10 days of operation after starting with a perfectly clean boiler before the saving due to higher steam temperature is sufficient to offset the steam used by the soot blower elements and 23 days before the lower flue gas temperature offsets the steam consumption of the other soot blower elements. The soot blowers were operated three times a day.

Conclusions drawn as the result of these tests are stated as follows:

1. Soot blower operation results in an increase in steam temperature at the superheater outlet, the gain from which is substantially greater than the steam consumption of the soot blower elements.

2. It also results in a reduction in the temperature of flue gases leaving the boiler unit, the saving from which is but little greater than the steam required to operate the soot blower elements.

3. Soot blower operation has a negligible effect upon draft loss.

4. The use of soot blowers appears to reduce the amount of slag deposited on the lower deck of boiler tubes. The slag deposit when soot blowers were not used, however, was not sufficient to cause the boiler to be taken out of service for cleaning. It is possible, however, that higher boiler ratings might alter this condition.

5. These conclusions might have been somewhat more favorable to soot blower operation had the elements been operated less frequently, or for a fewer number of revolutions, thereby reducing their steam consumption.

It may be stated that no boiler receiving its heat by the combustion of fuel is entirely free from soot while in operation. Increasing the draft will increase the accumulation of dust on the tubes, even particles of unburned coal may be carried beyond the combustion zone of the boiler setting. A small combustion chamber, low temperature in the furnace and improper air supply are conditions which cause incomplete combustion of the volatile gases and the rapid accumulation of soot on the heating surfaces. Where mechanical soot blowers are installed, it is customary to use them two or three times a day and if the tubes must be dusted with hand lances, this work should be done at least once a day. The tubes of fire-tube boilers should be scraped at least twice a month to remove the tarry soot and scale.

Boiler Scale and Its Removal

Feedwater that is not absolutely free of scale forming solutions will, in the course of continuous operation of a boiler, deposit impurities as precipitates which, due to the action of the heat, adhere to the heating surface as soft or hard scale depending upon the nature of the

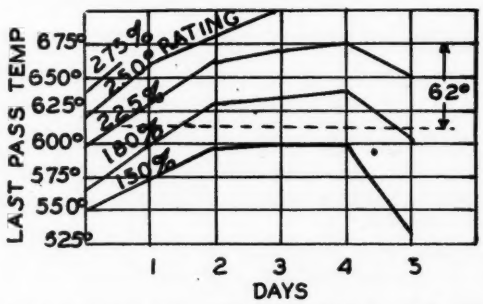


FIG. 3. RISE IN TEMPERATURE OF FLUE GAS AFTER DISCONTINUING USE OF SOOT BLOWERS

impurities. Any appreciable amount of scale in boilers is harmful not only because it increases the resistance to the transfer of heat but, at the high rates of steaming now encountered, this interference causes overheating of the boiler metal with danger of bags and blowouts.

So far as practicable, feedwater should be treated to remove all injurious impurities before going to the boiler but it is never safe to depend completely upon a chemical analysis of the feedwater and boiler water to ascertain the scale condition of the boiler. Regular inspection is necessary and scale removal by means of mechanical devices should be made a matter of routine. in some plants twice a month, others monthly, while a few having extremely effective feedwater treating systems use the scale removing devices only once a year.

Heat Conductivity of Boiler Scale

Tests made at the University of Illinois and reported by Huber D. Croft indicate that the values of the heat conductivity through a 4-in. No. 9 B.W.G. boiler tube with 0.1 and 0.2 in. of scale showed a heat decrease of 1.67 and 3.83 per cent respectively at 90 per cent rating and 2.99 and 5.98 per cent respectively at 225 per cent rating. It is also stated that for a clean tube 95 per cent of the resistance to heat transfer occurs on the gas side of the tube, 0.2 per cent occurs through the tube and the remaining 4.8 per cent is caused by the water

film on the inside of the tube wall. The conductivity of scale accumulated in a boiler tube under actual steaming conditions was found to be 6.7 per cent of the conductivity of steel, the density of this scale being approximately 140 lb. per cu. ft.

Scale accumulation can be quite effectively retarded by a systematic use of the blowoff. Usually blowing down is done at regular stated intervals, definite quantities of boiler water being removed at each blowdown. These periods and amounts are determined from chemical tests of the boiler water after various periods of operation at different rates of evaporation. By this means the concentration of scale forming material in solution can be controlled and excessive precipitation prevented.

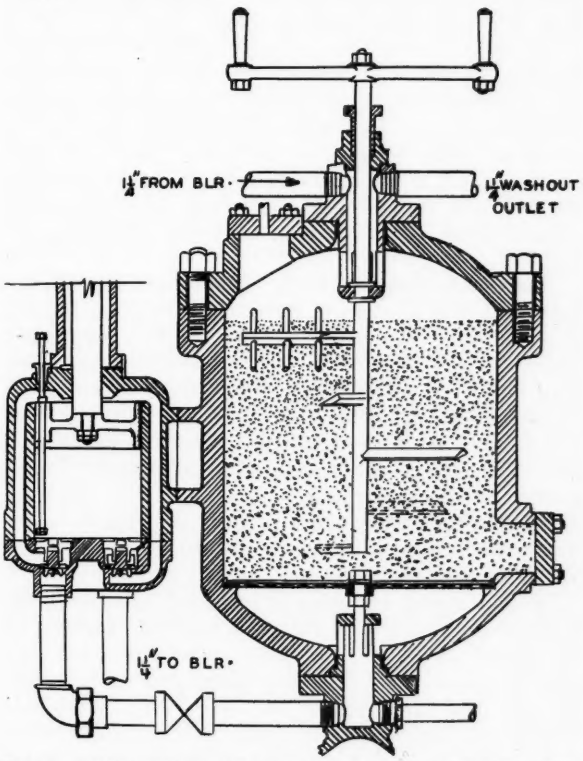


FIG. 4. DECONCENTRATOR THAT FILTERS AND RETURNS BOILER WATER

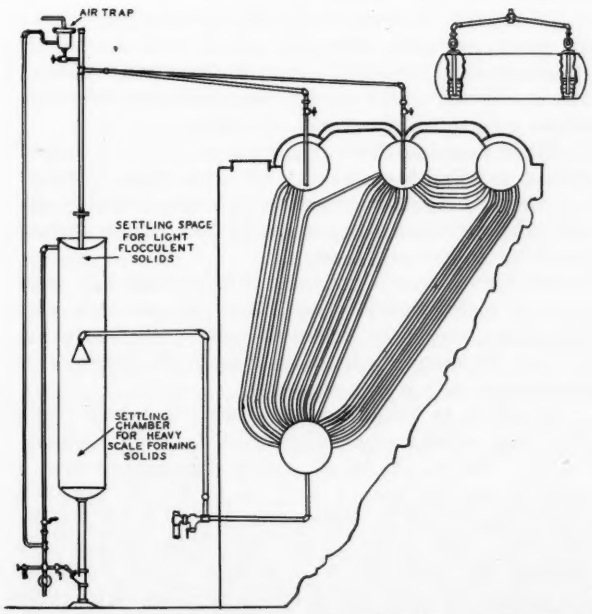


FIG. 5. DECONCENTRATION IS EFFECTED HERE BY SEDIMENTATION AND FLOTATION

It has been found that under certain conditions the allowable degree of concentration for water-tube boilers having horizontal tubes may be 500 gr. per gal. or 8550 parts per million; for those having vertical tubes and for horizontal return tubular boilers, the allowable concentration should be only about half of that for horizontal water tubes, i.e., 250 gr. per gal. or 4275 parts per million.

Where deconcentrators and continuous blowdown are employed, a maximum concentration as low as 100 parts per million is practiced. If the boiler is operated at higher rates of evaporation, the amount of sediment formed and the degree of concentration are proportionally increased. Waste of heat due to frequent blowdown can be greatly reduced by the use of a heat interchanger.

Deconcentrators have been developed to remove the scale forming precipitates from the boiler water while they are still in suspension. One type illustrated in Fig. 4 consists of a filter located outside the boiler setting through which boiler water is drawn from near the water level by means of a specially designed pump which returns it to the boiler. In passing through the filter, the water is cleared of impurities in suspension. Because of the lower temperature of the filter, this precipitate does not form scale and by back washing is removed from the filter bed.

Another type, shown in Fig. 5, includes a sedimentation chamber in which is circulated the equivalent of 25 to 50 per cent of the hourly evaporation. Suspended matter in the boiler water settles to the bottom of the tank and the clarified water returns to the boiler. Any oil in the boiler water collects in the top of the sedimentation chamber and is removed periodically by the opening of a drain valve.

Where the predominating impurities are soluble salts, a continuous blowdown system is recommended by some engineers. This system, a diagram of which is

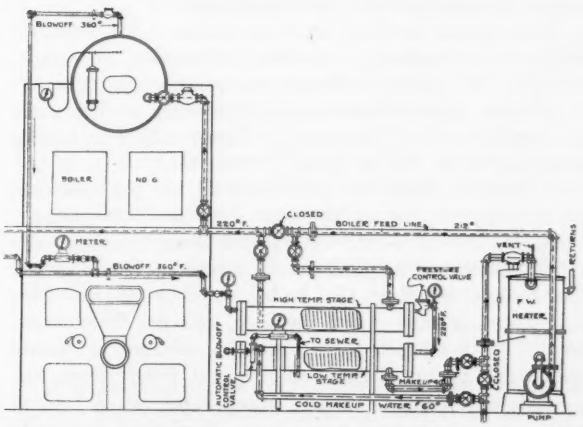


FIG. 6. HEAT EXCHANGERS PREVENT WASTE OF HEAT WITH CONTINUOUS BLOWDOWN SYSTEM OF DECONCENTRATING BOILER WATER

shown in Fig. 6, draws the water from the surface of the boiler water either by means of a skimmer or, in some cases, through some form of internal deconcentrator and passes it through a series of heat exchangers, where it gives up its heat to the incoming feedwater, and delivers the cooled blowoff water to the sewer.

Feedwater Treatment

IF THE ELIMINATION of scale-forming impurities in boiler feedwater were the only point to be considered, clean heating surfaces and maximum heat absorption could be easily maintained.

Unfortunately, an ideal feedwater is one that is neither scale forming nor corrosive and one that will not cause embrittlement, priming or foaming. Such waters do not exist naturally and the necessary treatment to make them conform to these requirements is accomplished by various methods. Demands for accurate treatment and control become increasingly important as pressures are increased.

SOME OF THE COMMON IMPURITIES FOUND IN FEEDWATER AND GENERAL TYPES OF TREATMENT

Constituent	Principal source of contaminating substance	Possible effect when present in boiler water	Treatment for removal from water
Suspended solids	Surface drainage, trade waste	Priming, foaming, sludge or scale	Plain subsidence, coagulation, filtration, evaporators
Silica	Mineral deposits	Scale	Plain subsidence, coagulation, filtration, evaporators
Calcium carbonate	Mineral deposits	Scale	Softening by chemical, by base-exchange material, evaporators
Calcium bicarbonate	Mineral deposits	Scale	Softening by heaters, by chemical or by base-exchange material, evaporators
Calcium sulphate	Mineral deposits	Scale, corrosion	Softening by chemical, by base-exchange materials, by evaporators
Calcium chloride	Mineral deposits	Scale	Softening by chemical, by base-exchange materials, evaporators
Magnesium carbonate	Mineral deposits	Scale	Softening by chemical, by base-exchange materials, by evaporators
Magnesium bicarbonate	Mineral deposits	Scale	Softening by chemical, by base-exchange materials, by evaporators
Magnesium chloride	Mineral deposits	Scale, corrosion	Softening by chemical, by base-exchange materials, by evaporators
Free acids	Mine drainage, trade waste	Corrosion	Neutralizing acid, followed at times by softening or evaporation
Sodium chloride	Sewage, trade waste, mineral deposits	Inert but may be corrosive under some conditions	Evaporator
Sodium carbonate	Mineral deposits	Priming and foaming, embrittlement	Evaporator
Sodium bicarbonate	Mineral deposits	Priming and foaming, embrittlement	Evaporator
Carbonic acid	Absorption from the atmosphere, mineral deposits, decomposition of organic matter	Corrosion	Deaerator
Oxygen	Absorption from the atmosphere	Corrosion	Deaerator
Grease and oil	Trade waste	Corrosion, deposits, priming, foaming	Coagulation, filter, evaporator
Organic matter and sewage	Domestic and trade wastes	Corrosion, deposits, priming, foaming	Coagulation, filter, evaporator

As shown above, mineral matter in most water consists of a relatively few elements combined to give a number of different compounds. Calcium, magnesium, sodium and potassium are the most common bases and bicarbonates, carbonates, sulphates, chlorites and nitrates, the most common acid radicals.

Purification methods include: plain sedimentation; sedimentation aided by chemicals; filtration; chemicals, colloidal or base exchange materials; evaporation; deaeration and deconcentration are some of the more common methods of treatment. In the modern plant, a combination of two or more is often used.

Softening water by chemicals or by the base exchange methods is widely used. In the first method, chemicals are added to convert the scale forming salts into insoluble salts which can be filtered or precipitated out before entering the boiler or into soluble non-scale-forming salts. For instance, calcium bicarbonate treated with hydrated lime gives a calcium carbonate salt which is but slightly soluble and precipitates out.

Calcium sulphate on the other hand, when treated with soda ash gives a precipitate of calcium carbonate as well as sodium sulphate a soluble non-scaling salt which remains in the water. Combination of lime and soda ash or soda ash and caustic soda treatments are widely used in power plant practice usually in what is known as the hot process where the reactions take place at or near 210 deg. F.

Reactions take place with greater speed in hot than in cold solutions and as boiler feedwater is invariably heated, the hot process is generally preferred. Reactions are often speeded up and sedimentation and coagulation improved by the use of additional chemicals such as sodium aluminate or alum.

In zeolite or the base exchange method of softening, another widely used process, the scale-forming salts are converted into soluble salts. For instance, calcium carbonate treated with zeolite is converted into sodium carbonate which remains in the water. Zeolite is especially adapted to waters not excessively hard and where the hardness varies considerably over short periods as proportioning of chemicals to meet the changes is not required.

Sometimes chemicals are introduced directly into the boiler either as a separate operation or as an additional step following the usual treatment. This additional treatment may be in the form of a boiler compound and may derive its effectiveness either from chemical reaction or colloidal action which absorbs solid particles and scale in the boiler and preventing it from depositing. The entire mass is removed by blowdown or some system of deconcentration. Because of the breaking down of certain compounds at high temperature boiler waters for pressures of 200 or 250 lb. or over are subjected to such treatment.

Evaporation is becoming of increased importance for high pressure plants, in fact it is standard practice in all central stations. Evaporated makeup does not necessarily mean that absolutely pure feedwater is obtained. The carryover of the evaporators, condenser leakage and high evaporation rates in these boilers make it necessary to keep a close watch on the boiler water conditions. Treatment of water going to the evaporator is treated in many plants.

Deaeration, used primarily for control of oxygen in the water, has some effect on calcium and magnesium bicarbonates by removing some of the carbon dioxide. This action may under certain conditions remove around 40 per cent of the bicarbonate hardness.

When treating feedwater, however, it is necessary to keep in mind the necessity for preventing corrosion and embrittlement. Magnesium chloride is highly soluble and corrosive since hydrochloric acid is formed under the influence of heat.

Sodium salts are generally soluble and not scale forming under ordinary conditions but at high concentrations may cause operating trouble through priming and foaming. Sodium chloride in the presence of magnesium salts is also corrosive.

In order to inhibit embrittlement a definite ratio of sodium carbonate to sodium sulphate should be maintained. The A. S. M. E. boiler code recommends a ratio of not less than 1 to 1 up to 150 lb. pressure, 1 to 2 up to 250 lb. pressure and 1 to 3 for 250 lb. and over. This matter is still the subject of extensive research and although it is probable other inhibitors are equally effective, the carbonate sulphate ratios given above are well established as a safe index of protection at least for the pressure range covered.

Effect of Water Circulation in Boilers

WHILE GOOD circulation in a boiler is important from the standpoint of good boiler operation, the effect of water circulation upon boiler efficiency is probably not as important as it was once thought to be. In many heat transfer appliances, the rate of heat transmission increases as the fluid velocity increases. On the reception side, high fluid velocity leads to rapid replacement of warmed fluid by new and colder fluid which increases the temperature difference between the heating and heated mediums, hence, it also increases the rate of heat transfer. It is well known, for instance, that a steam radiator used for heating air transmits a vastly greater quantity of heat when the air is blown upon it by a fan than when the air surrounding it is comparatively still. Even in a coil used for heating water, the transmission of heat is more effective when the water is given rapid circulation. The reason for this is due, of course, to the fact that the rapid circulation of air or water constantly removes from the heating surface the heated medium and replaces it with a cool one and the rate of heat transmission increases approximately as the square of the difference of temperature on the inside and outside of the coil.

In the case of steam boilers, the conditions are considerably different. There is, in all modern types of boilers, a rapidity of circulation sufficient to keep all the water surrounding the heating surfaces at nearly the same temperature as that of the steam, so that the difference of temperature on the two sides of a square foot of heating surface remains practically constant. The quantity of heat transferred can scarcely vary much with the water velocity and the efficiency does not in any marked degree depend upon the water circulation.

Effects of Good Circulation

Circulation is important, however, in that it reduces stresses arising from differences in temperature and prevents to a certain extent the accumulations of mud or scale in places where they are least desirable.

Many experiments have been undertaken to determine what inclination of boiler tubes is most conducive to evaporative capacity and efficiency. While various boiler makers have selected certain slopes, the experiments which have been made to determine tube slope do not seem to have been conclusive. As a matter of fact, equivalent efficiencies have been obtained with tubes of practically all degrees of slope.

The natural circulation in most water tube boilers is sufficient without necessitating external aids. In shell boilers, the circulation problem is more serious and many troubles have resulted due to poor circulation with the result that mechanical aids to circulation such as the hydrokineter have been developed.

Some authorities have figured the maximum water velocities in tubes of B. & W. type boilers in excess of 100 ft. per sec. but it is safe to assume about 20 ft. per sec. as about the usual maximum. There have been attempts made to measure this velocity but the results have been inconsistent so that we may say that the circulation velocity of water in the tubes varies from 2 ft. to 20 ft. per sec. as maximum in this type boiler.

Steam Releasing Surface

It is usually stated that there must be a water surface of sufficient area to release the steam bubbles from the water to prevent priming, and that a steam-storage space must be provided to allow the water particles not evaporated but entrained in the steam to settle out. The usual allowance for steam space in a shell boiler is about one-third of the volume, and the ratio of heating surface (HS) to releasing surface (RS) is HS/RS = 3.5. The ratio in the ordinary return tubular boiler is 17, in the standard three drum 14-high, 21-wide B. & W. it is 31, in the B. & W. cross-drum type 96 and in the boilers of the Almy, Ward, and Belleville types it is from 2000 to 7000.

As all these boilers prime occasionally and all can be run without priming, it will be seen that the releasing surface has nothing to do with priming. As a matter of fact, priming will not occur unless the boiler water is impure or soapy due to the presence of colloids.

According to Orrok in a paper before the A. S. M. E., in general because of the lower specific volume, high-pressure steam needs much less releasing surface and steam space than low pressure steam. Boilers should work much better at high pressure and much less trouble is to be expected with increasing pressures.

Heat rate of a steam engine or turbine is the total heat content of the steam entering the machine plus the reheat but minus the total heat which can be returned to the boiler.

On engines operating on a simple Rankine cycle, the heat returnable is the heat in the water at the saturation temperature corresponding to the exhaust pressure. Thus, in condensing plants, this is usually referred to as the hotwell temperature even though there is sometimes a heat drop of a few degrees through the condenser.

For the complete power plant, whether it be steam or internal combustion engines, the heat rate is the high calorific value of the fuel multiplied by the pounds or cubic feet of fuel consumed per unit of output.

The quality of steam or any other vapor is commonly expressed in one of two ways, depending upon the condition. If superheated, the quality is expressed as degrees of superheat in degrees Fahrenheit, while, if the vapor is wet, the quality is expressed by a dryness factor. If the steam contains two per cent moisture, its quality is said to be 98 per cent, indicating that 98 per cent of it is steam and two per cent condensed liquid.

Most steam used in power plants today is superheated and, as there is a definite limit beyond which designers feel safe, it is becoming more common to use the total temperature of steam rather than its superheat. Steam at 345 lb. gage with a total temperature of 735 deg. F. is the same as 345 lb. gage steam superheated 300 deg. F.

Utilization of the heat of the flue gases to heat the air for combustion before reaching the furnace was first used successfully by Howden in connection with marine boilers.

Importance of Baffling in Securing Economy

TIGHT, WELL-BUILT BAFFLES PREVENT SHORT CIRCUITING OF GASES AND PERMIT HIGHEST POSSIBLE EFFICIENCY. ANALYSIS OF HEAT LOSS IN GAS LEAVING BOILER

IN THE DESIGN of a steam boiler, the number and arrangement of the baffles have a marked influence upon the boiler efficiency. It is, therefore, imperative that for a particular boiler the baffling should be that which will provide the highest efficiency under normal operating conditions.

While the arrangement of baffles is important, there are so many factors bearing directly upon what constitutes a proper installation, that it is impossible to set any fixed rules. In general, there are three types of baffling: 1, those placed at right angles to the tubes (vertical baffles); 2, those parallel with the tubes (horizontal baffles); and 3, those inclined at an angle.

Arrangement of the baffles largely determines the length of the gas passage through the boiler and therefore, the velocity with which the gases sweep the heating surface. A boiler whose heating surface is arranged to provide long gas passages of small cross section will be more efficient than a boiler in which the gas passages are short and of large cross section.

From this, it is apparent that if the baffling is to be effective, there must be no possibility of gas leakage through the baffles, that is, the gases must be compelled to travel the entire length of the gas passage rather than short circuit from one pass to another. Short circuiting of gases is a common fault and exists more often than most operators imagine. The baffling always should be inspected when the boiler is shut down for cleaning and repairs.

In making inspections, baffles should be examined not only for large openings but for the smallest cracks. These should be cemented tightly. If this is not done, concentration of flow gradually forces a larger opening until failure of the baffle results. The installation of pyrometers in the top of the last pass, fitted with recording devices if possible, is a ready safeguard against operating for any length of time with the baffles out of order. In a certain installation, consisting of a 500-hp. Stirling boiler, the effect of a broken baffle is shown by a record of the temperatures taken. Under the same conditions of furnace temperature, with the baffles in good condition, the temperature at the first pass was 1148 deg. and the top of the last pass, 545 deg. while, with a defective baffle, the temperature at the top of the first pass dropped to 662 deg. due to non-circulation at this point. At the same time, the temperature at the top of the last pass was 1778 deg. The efficiency had dropped from 78.8 to 28.2 per cent.

This, of course, was a severe case for upon examining the boiler it was found that a 32 by 29-in. hole had been formed in the center of the first baffle. A smaller opening would have less serious results but the drop in efficiency would be noticeable.

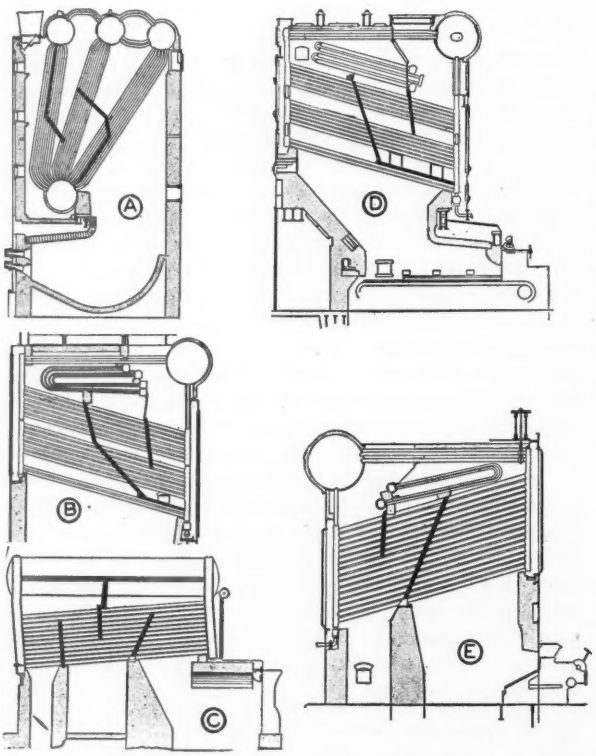


FIG. 1. DIFFERENT TYPES OF BAFFLING IN DIFFERENT BOILERS

HEAT LEFT IN GASES

To maintain boiler operation at the point of best economy, it is necessary to watch closely the heat left in the gases. In connection with the subject of baffling we have seen how the uptake temperature is an index to the condition of the baffling in the boiler. The allowable uptake temperature will vary, of course, in different plants due to different conditions and different fuels. There is, for instance, a loss due to moisture in the fuel and also one due to the formation of water due to the combustion of hydrogen. These losses can be determined with a fair degree of accuracy. The heat loss due to the dry chimney gases is, of course, dependent upon the weight of dry flue gas per pound of fuel. This weight is easily calculated from the formula

$$\frac{11\,CO_2 + 8\,O_2 + 7\,(CO + N_2)}{3\,(CO_2 + CO)} \times \frac{\%\text{ carbon burned}}{160} =$$

lb. of dry gas.

In order to determine the dry gas loss rapidly, J. G. Huntoon devised the accompanying chart, Fig. 2. In order to illustrate the use of this chart, suppose, by means of the above formula, the amount of dry gas produced equals 9.53 lb. per lb. of fuel. Suppose further that the flue gas temperature is 300 deg. and the room temperature 80 deg. Entering the chart at a flue gas temperature of 300 and reading horizontally the initial air temperature of 80, proceed vertically downward to

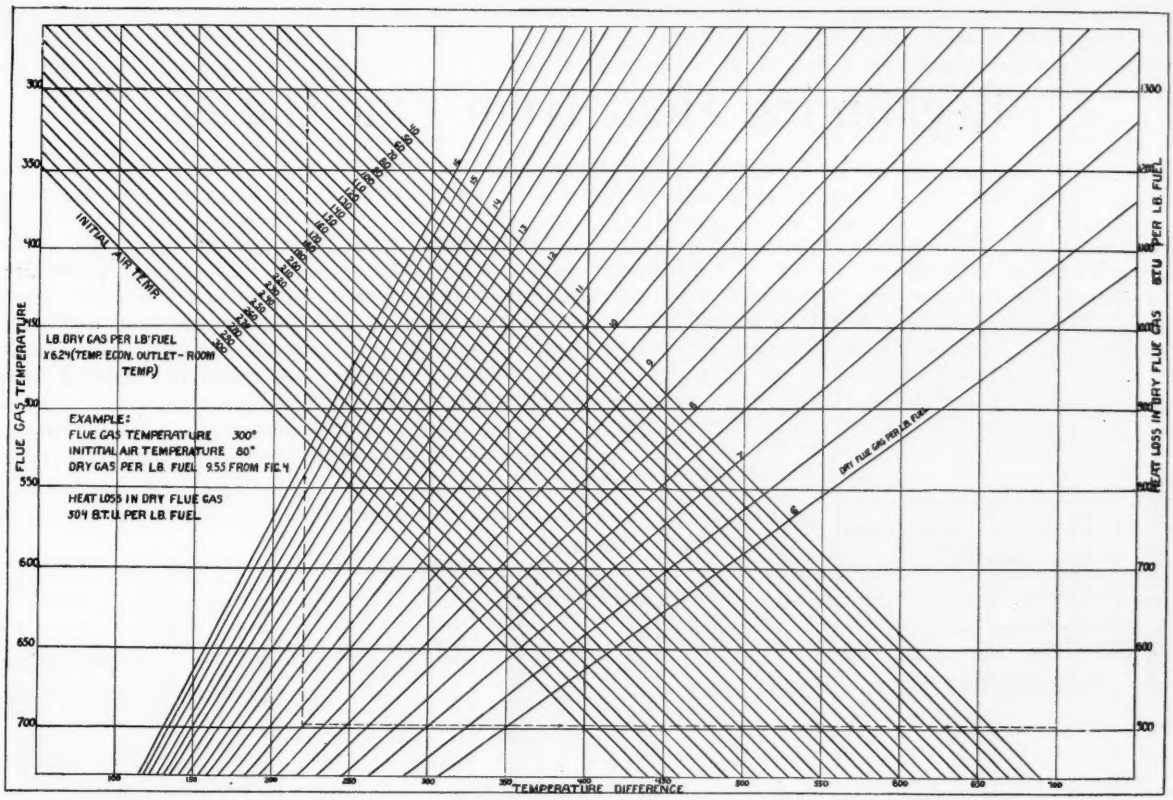

FLUE GAS TEMPERATURE
INITIAL AIR TEMP.
LB. DRY GAS PER LB. FUEL X 6.24 (TEMP. ECON. OUTLET - ROOM TEMP.)
EXAMPLE:
FLUE GAS TEMPERATURE 300°
INITIAL AIR TEMPERATURE 80°
DRY GAS PER LB. FUEL 9.55 FROM FIG. 4
HEAT LOSS IN DRY FLUE GAS 504 B.T.U. PER LB. FUEL
DRY FLUE GAS PER LB. FUEL
TEMPERATURE DIFFERENCE
HEAT LOSS IN DRY FLUE GAS B.T.U. PER LB. FUEL

FIG. 2. HEAT LOSSES DUE TO DRY CHIMNEY GASES (ASSUMING THAT $CO_2 + CO + O_2 = 19$)

the dry gas per lb. of fuel, 9.53 and then horizontally to the heat loss in the dry flue gas which is found to be 504 B.t.u.

The loss due to moisture in the fuel is easily calculated by means of the formula given in the A. S. M. E. code:

$$\frac{\%\text{ moisture}}{100}\ 1089 + 0.46 \times T_{EO} - T_F = \text{loss in B.t.u.}$$

In this formula T_{EO} denotes the temperature at the economizer outlet and T_F, the temperature of the fuel.

The heat loss due to incomplete combustion of carbon is best determined by means of the formula

$$\frac{CO_2 + CO}{CO} \times \text{carbon burned per lb of fuel} \times 10{,}160 = \text{B.t.u. loss.}$$

The foregoing formulas merely provide the means of determining the various losses. They do not necessarily show what to do after the losses are determined, for this varies widely with individual plant conditions. The frequent calculations of these losses and the laying out of a maximum value for each controllable loss will tend to bring the operation of the boiler room down to, or perhaps we should say up to, a consistent basis.

It is difficult to state what each of these losses should be because of the widely varying conditions. With regard to the allowable temperature of the flue gases, for instance, there used to be an old rule which stated that the temperature of the escaping gases should be somewhere near 100 deg. F. above that of the steam in the boiler. Where there is only a boiler concerned, this rule may be somewhere near correct but when a boiler is operated in connection with an economizer, the temperature of the stack gases is determined by the temperature of the incoming feedwater. When an air preheater is used, the stack temperature allowable will depend upon the temperature of the incoming air.

In a recent survey of power plants published in the December 15 issue of Power Plant Engineering, the average outlet gas temperature at the economizers in 10 power plants, was 508 deg. In these 10 plants, the lowest temperature was 338 deg. and the highest 683 deg.

BEAUHARNOIS ELECTRIC CO., Quebec, has begun preliminary work on proposed hydroelectric generating plant using waters from the St. Lawrence River. The power plant will be equipped for an initial output of 200,000 hp. and it is expected to develop the project, by 1933, to the ultimate capacity of 500,000 hp. Water will be conducted to the plant through a power and navigation canal about 600 ft. wide and 14 mi. long. It is reported that the Montreal Light, Heat & Power Co. will use a large block of power from the new plant and that the Power Commission of Ontario will purchase about one-half of the ultimate output.

WHEN MAKING saturated steam from water, the heat added is used in three ways: to raise the temperature of the water, overcome the resistance to rearrangement of molecules and to do work in displacing the surrounding media. These three heat additions are known as sensible heat, internal latent heat and external latent heat.

Reclaiming Heat from Flue Gases

TYPES OF AIR PREHEATERS AND ECONOMIZERS AND HEAT SAVINGS DUE TO THEIR USE

PREHEATED AIR for stoker operation has advantages, as listed by Joseph G. Worker: 1. Efficiency of stoker, boiler and superheater increased seven per cent. 2. Rate of operation raised from 500 to 700 per cent rating. 3. Combustible loss in refuse reduced to less than 7/10 per cent of B.t.u. in coal or seven per cent combustible in refuse. 4. 80,000 B.t.u., for maximum rating, can be liberated per cubic foot of furnace volume per hour. 5. Greater ease in burning smoky coal, smokelessly. 6. Elimination of continual cooling and heating of fine particles of ash by introduction of heated air in refuse, resulting in easier handling of refuse of fuel bed. 7. Decrease in amount of stoker space required for drying the coal, making more effective the actual carbon burning zone.

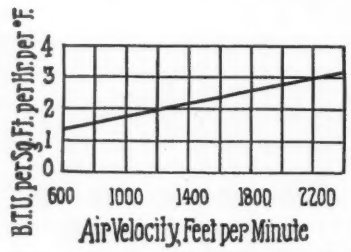


FIG. 1. HEAT TRANSFER IN AIR PREHEATERS

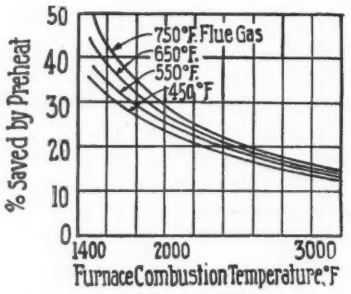


FIG. 2. SAVINGS ACCOMPLISHED BY PREHEATING AIR

Heat transfer effected by air preheaters at different velocities of air is illustrated in Fig. 1 and saving secured by preheating air is shown in Fig. 2.

In the Holland station design, the amount of air preheater surface adopted was 46.3 per cent of the total heating surface, representing nearly four times the actual boiler heating surface and nearly three times the economizer surface. Adoption of so high a percentage of air preheater surface was due to the low cost of this type of heating surface. The relative costs per square foot for the various types of heating surface in this plant, taking boiler heating surface as a base and including erection cost, were: boiler 100, superheater 29.2, gas reheater 21.5, economizer 23.2 and air preheater only 4.4.

Two general types of preheaters are in use. The convection type may be subdivided as plate or tubular whereas the regenerative type employs a metal rotor which alternately is heated by the gases and delivers heat to the air. A tubular air preheater of the convection type, using the counterflow principle of heat transmission, is illustrated in Fig. 3.

In the plate type of heater, the gas and air travel through alternate passages between the plates. One type consists of a pile of thin rectangular plates held apart by helical wire spacers and so arranged that air and gas may pass through alternate spaces. Another type uses plates of diamond-shaped cross section.

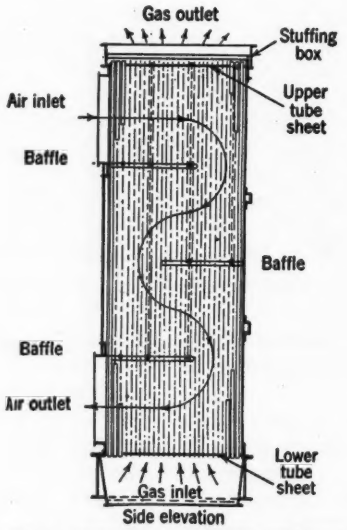


FIG. 3. TUBULAR AIR PREHEATER OF CONVECTION TYPE

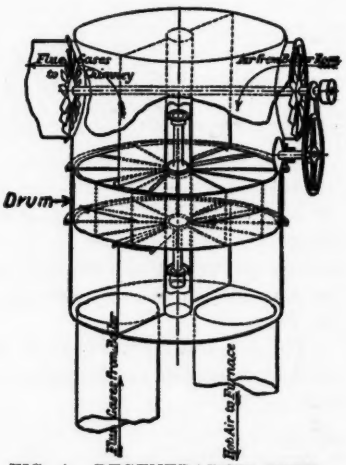


FIG. 4. REGENERATIVE TYPE PREHEATER

A regenerative type preheater is illustrated in Fig. 4. This has two semi-cylindrical sections, air being drawn into one by a fan at the top and passed out at the bottom, while hot gases pass up through the other section and are withdrawn by another fan on the same shaft. Heat transfer is effected by a slowly-rotating porous drum, in which the spaces between radial blades are filled with corrugated and plain sheets forming arcs of circles concentric with the drum axis.

Cleaning and corrosion are important factors affecting the performance, especially of the convection type, of air heaters.

In an existing setting of an air preheater at the Colfax Station of the Duquesne Light Co., two heating elements are placed back to back, the central vertical third of the heater being occupied by a bypass for the flue gases, which ascend through the preheater by nat-

ural draft. The air passes down to a suction fan which discharges it to the stoker wind box.

Gain in efficiency due to preheating varies from 5½ per cent at 114 per cent rating to 7 per cent at 200 per cent rating. Tests on this preheater with and without preheater connection gave the results shown in Figs. 5 and 6 for gain in efficiency, also furnace and gas temperatures from the fuel bed to a point beyond the preheater. The fuel-bed temperature increase with preheated air is much greater than the wind-box increase, due to the reduction in excess air. For 114 per cent rating, the draft loss through the boiler was reduced from 0.31 to 0.24 in. and for 200 per cent rating from 0.94 to 0.67 in., partly offsetting the reduction in stack draft with the cooler exit gases. The fan power utilized was less than 0.4 per cent of the coal fired.

Heat Recovery with Economizers

Economizers increase resistance to flow of the hot gases, also reduce flue gas temperatures, so that natural

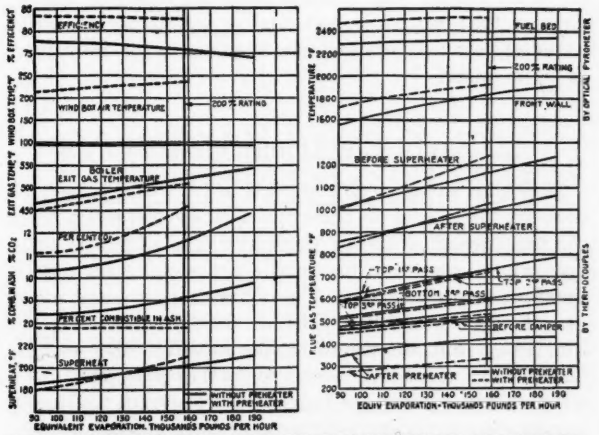


FIG. 5. COMPARATIVE PERFORMANCE WITH AND WITHOUT USE OF PREHEATER

FIG. 6. FURNACE AND GAS TEMPERATURES WITH AND WITHOUT USE OF PREHEATER

draft is generally inadequate when economizers are used and induced draft equipment must be installed. Only in large plants, therefore, can use of a fuel economizer be justified to show a profitable investment after taking into account interest, depreciation and maintenance charges, not only of the economizer but also of the induced draft apparatus.

Economizer Types

Two types of economizers are in use, those provided with cast-iron tubes and those fitted with steel tubes. Many engineers favor 250 lb. as the highest pressure for which cast-iron economizers should be used while others place the pressure limit at from 150 to 350 lb.

Formerly, cast iron was used because it is less easily corroded but steel economizer tubes may be protected within and without by protective coatings and externally by cast-iron covering; also deaeration, now commonly used, reduces internal corrosion.

Besides being suitable for high pressures, wrought-steel-tube economizers generally are less bulky and, especially for higher pressures, less expensive and more easily housed with the boiler in a single setting, thus reducing leakage and radiation losses. Heat transference is also said to be better in steel economizers, the economizer tubes sometimes being fitted with cast-iron rings in order to present more heat conducting surface.

Heat Transference

Relation between water and flue gas temperatures in an economizer is shown in Fig. 7 while the amount of economizer heating surface required per boiler horsepower and the amount of heat absorbed, per square foot

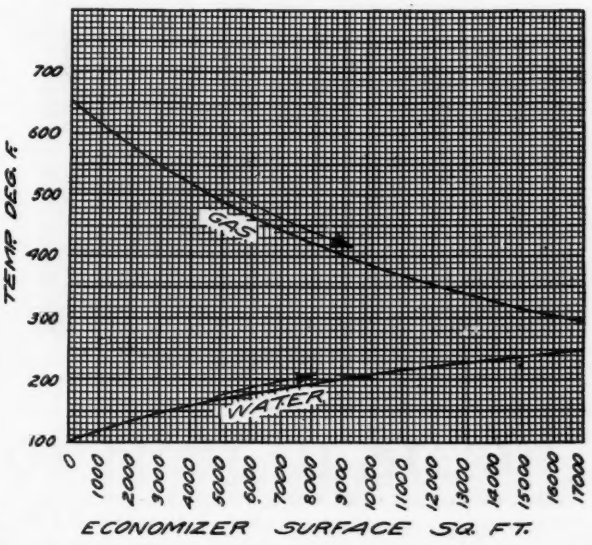


FIG. 7. RELATION BETWEEN WATER AND GAS TEMPERATURES

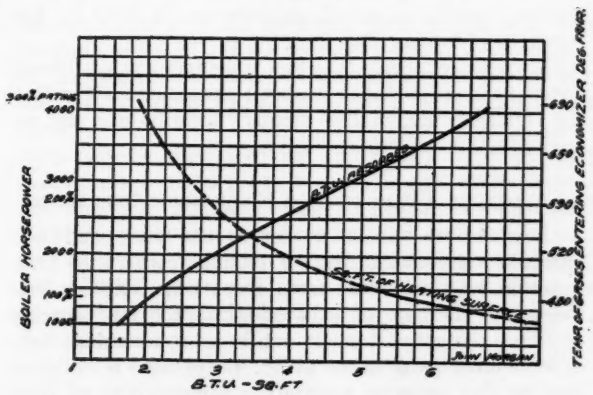


FIG. 8. ECONOMIZER HEATING SURFACE PER BOILER HORSEPOWER AND HEAT ABSORBED PER SQUARE FOOT PER DEGREE REDUCTION IN FLUE GAS TEMPERATURE

per degree reduction in flue gas temperature are given in Fig. 8. In order to take up as much heat as possible, economizers now operate on the counter-flow principle in which water and gas move through the economizer in opposite directions. Mechanically operated scrapers, which automatically move up and down on the tubes to remove the soot and dust, are still used extensively for the cast-iron type but the use of soot blowers is now coming into favor even for cast-iron economizers. Where economizers are used, provision is sometimes made for bypassing flue gases around the economizer sections when the economizer is out of service.

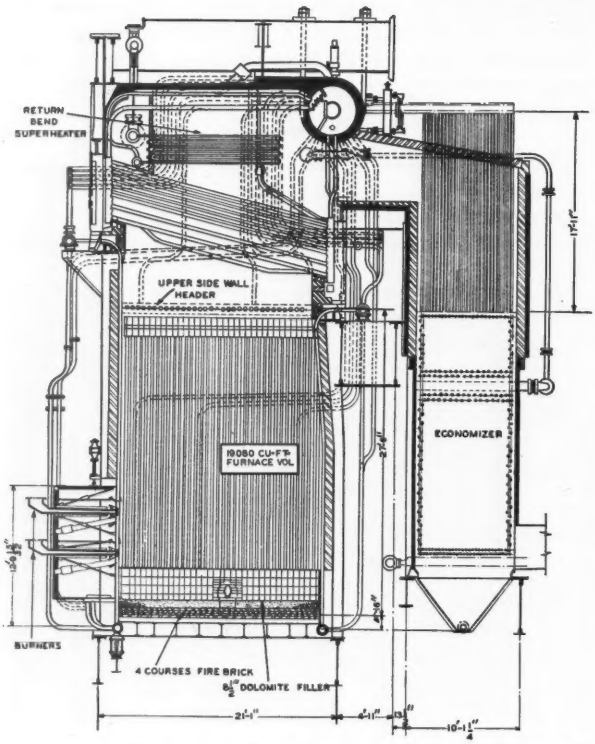


FIG. 9. STEEL STEAMING ECONOMIZER INSTALLED IN REAR OF BOILER OPERATING AT 1350 LB. PRESSURE

Typical installation of a steel-tube steaming economizer set back of a boiler as installed at the Deepwater Station, operating at a drum pressure of 1350 lb. per sq. in., is shown in Fig. 9.

Integral economizers, which in effect are additional water heating surface, are sometimes installed within the boiler setting, giving compact installations and reducing radiation losses.

Conditions Favorable for Economizer Operation

Economizers will show best results where sufficient natural or mechanical draft is available; where the feedwater is relatively free from incrusting solids; where there is a shortage of exhaust steam for feed heating or where the exhaust steam can be used advantageously at some other point in the plant; where there is sufficient heat in flue gases to maintain a temperature of from 250 to 275 deg. F. at the economizer outlet and where care is used to keep the tube surfaces clean.

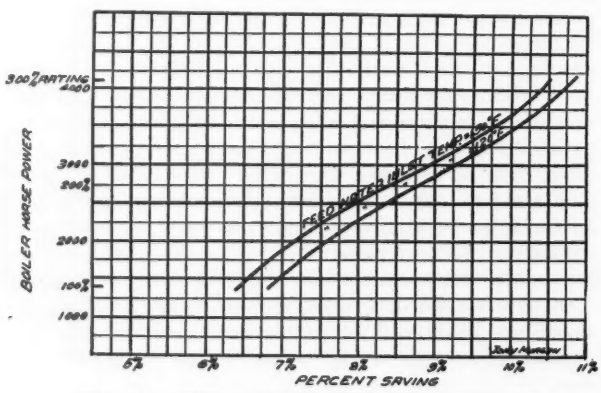


FIG. 10. FUEL SAVINGS DUE TO ECONOMIZER

With an economizer installed, the boiler should give better service because the feedwater will always be heated whenever the boiler is fired. A saving of fuel amounting to about one per cent for each 11 deg. F. that the water is heated by the economizer may be reasonably expected but cost of producing extra draft must be charged against this saving. An economizer also gives a reserve heat storage which will assist in carrying the boiler plant over peak loads. Fuel savings secured by the use of an economizer are illustrated in Fig. 10.

Heat balance of a complete plant is the best indication of the proper method of feedwater heating and whether to recover waste heat by use of an economizer alone or an economizer supplemented by an air preheater. Net saving due to heat recovery is not the only criterion in the decision; the slower water velocity in the economizer, which increases tendency to precipitate solid matter, also removal from the boiler of undue stresses that would be set up by admitting directly water of low temperature are arguments for installing an economizer.

Early Electrical History

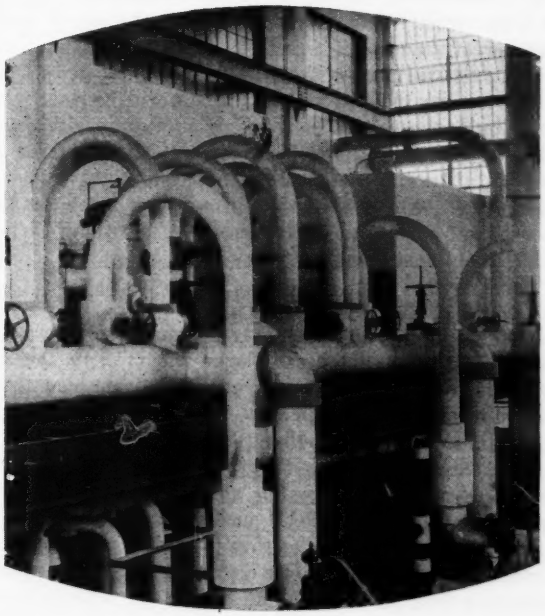
Looking back over the early history of the electrical industry, it is easy to trace the slow development from the first practical use of electricity, the magnetic compass which came into use in the European countries in the fourteenth century. The Chinese may have made use of this as reported between 3000 and 2000 B. C. but if they did, the use of it, like so many other things, ended there and did not lead to further progress.

Dr. William Gilbert, in the early 1600's, gathered together available material on electricity and magnetism and first explained the action of the compass. In 1602, Guericke made a static electricity machine from a revolving ball of sulphur. About 1675, Sir Isaac Newton and Frances Hawksbee both improved this machine by substituting a glass ball for the sulphur one. About the middle of the eighteenth century, the Leyden jar was discovered and Benjamin Franklin is said to be the first to have used them in series probably previous to his famous lightning experiments in 1752.

In 1790, Galvani discovered the flow of electricity but the so-called Voltaic pile or cell discovered by Alesandro Volta in 1799 was the first means of producing electricity in usable amounts and made possible the early experiments of Sir Humphrey Davy in the early nineteenth century on arc lights. Probably Oersted, in 1820, was the first to discover the magnetic effects of an electric current and although Farady used it in 1820, it was not until 1831 that he discovered the principle of the dynamo.

Although Swan in England and Edison in America are generally credited with this invention, the history of the arc and incandescent light is somewhat involved. Edison's claim seems better established, because his work included the development of generating equipment and control methods as well, putting it on a commercial basis with the opening of the Pearl Street Station in New York the same year.

PRECAUTIONS must be taken to prevent the heat in the steam from escaping by radiation or leakage and to convert as much as possible of its energy into work. In this endeavor, important factors are piping, turbine design, feedwater and steam heating, high superheat, good condenser practice.



Economical Use of Heat in Steam

By FRANK O. ELLENWOOD
Professor of Heat-Power Engineering
Cornell University

BIGGER STEAM power plants continue to be built because they represent the most economical way to meet the increased demand for power. Better steam stations are erected today than ever before because sufficient knowledge is now available to enable mechanical engineers to design plants of high thermal efficiency and at the same time keep the first cost down to a justifiable figure.

In the boiler room, much effort is put forth to deliver a steady flow of steam at some particular pressure and temperature, because these two characteristics of steam are of the utmost importance in the continuous production of mechanical energy. Consequently, when the steam flows from the boiler to the turbine room care should be taken to prevent a serious loss of available energy by throttling or by transmission of heat. Both of these losses may be kept down to a value that means the lowest net cost to the plant for each unit of energy delivered by it.

Piping Economy

Bigger piping means a less amount of throttling but, on the other hand, larger pipe lines cost much more and are more expensive to insulate, hence the size of piping needs to be carefully calculated for any given plant.

Making a calculation to determine the size of piping and thickness of insulation, however, does not mean that the most economical selection can always be made. This problem is similar to many others in power plant design. The difficulty is due, not to lack of knowledge of the laws of throttling or of heat transmission but solely to the uncertainty of the economic factors involved. For example, some of these uncertainties are: probable life of the plant, load factor during each year of this life, the cost of capital during the life of the plant and the value of the energy saved. Naturally, all of these questions may be given different answers by different engineers for any given plant, because no one can be certain just what may happen during the life of the equipment. Past records of our power plants have, however, in general been so satisfactory to the stockholders that they are still willing to risk their money in new plants as designed by reputable engineers.

Better Turbine Economy

Large steam turbines that are being installed in so many plants today are far better machines than the smaller ones they displace. This is true because cost and floor space per kilowatt are probably both less, construction is more durable and thermal economy is likely to be far superior. The reason for the improvement in thermal efficiency is due to a number of things. In the first place, nearly all of our large modern turbines use steam of higher pressure and temperature than formerly and thereby increase the energy available for the production of work from each unit weight of steam passing through the turbine. Secondly, by using a high degree of superheat the turbine is able to reduce materially the losses due to moisture in the nozzles and buckets.

By improvements in the design and manufacture of

the nozzles and buckets there is a smaller loss due to fluid friction and turbulence as the steam finds its way at high velocity from nozzle to bucket through a large number of stages. Keeping the leakage down and designing the turbine so that the absolute velocity of the steam leaving the last row of buckets will be small also contributes materially in reducing the losses within the turbine. The rotational losses, in addition to those of the main bearings and the pump, also add a small amount to the others so that in our best machines the sum of all turbine losses amounts to less than 15 per cent of the available energy.

Regenerative Heating

Use of high steam pressures has made it almost the universal custom to operate large turbines on the regenerative cycle, which means utilizing steam bled from the turbine at various stages to heat the condensate before it is fed to the boiler. This procedure causes a marked improvement in the thermal efficiency of the turbine because it reduces the amount of energy lost to the circulating water of the condenser. The amount of steam passing through the throttle valve per kilowatt-hour is greater for a turbine operating on the regenerative cycle than on the Rankine having the same exhaust pressure and the same throttle pressure and temperature. But the steam rate of a turbine, i.e. the pounds of steam per kilowatt-hour, is only part of the story in such a comparison, if real information be desired regarding the thermal performance of the two turbines.

Difference in the amount of energy returned to the feedwater in the two cases is so large that it cannot be ignored in any fair comparison. All steam turbines are justly credited with the energy that they deliver back to the boiler room by means of feedwater heaters, which are supplied with steam bled at various stages of the turbine. The higher the throttle pressure, the more advantageous becomes this process of regenerative feedwater heating for two reasons. In the first place, as higher pressures are used the heat content of the liquid becomes a greater and greater percentage of the heat content of the steam; thus high pressures afford better opportunities to use regenerative feed heating. Secondly, the weight of steam that must pass through the last few stages of a big turbine is much reduced by bleeding and, consequently, the size and cost of the exhaust shell are materially decreased. Furthermore, anything that will enable the designer of a big turbine to keep down the length of buckets in the last stage will most certainly contribute to his own peace of mind when the turbine is put into service.

Intermediate Reheat

Use of high pressures in a turbine, however, makes it desirable to use high temperature at the throttle, or employ reheating at one or more points. Otherwise, the high ratio of expansion employed with high pressure will cause trouble from the large amount of moisture formed in the steam at the low-pressure stages. This moisture causes extra loss of energy in the buckets and nozzles and also produces rapid wear of the buckets.

Reheating the steam at one or more points in its passage through the turbine is an effective way of getting rid of the troubles due to the moisture in the steam but considerable extra piping is needed to carry the steam to the boiler room and back to the turbine again. This piping may be largely eliminated, if only a small degree of superheat is needed at the reheating points, by using high-pressure steam passed through special reheaters placed near the turbine. Use of live steam alone, however, to furnish the energy for reheating necessitates a number of reheaters placed at different points when throttle pressures are high, because the saturation temperature corresponding to boiler pressure is not high enough to give with one reheating, a sufficient degree of superheat to prevent low quality steam in the latter stages of the turbine. On the other hand, there is no such limitation imposed upon the degree of superheat attainable with a gas reheater, that is, one which receives its heat from the hot furnace gases. In fact, this type of reheater may furnish steam at any temperature that can be sustained by the materials involved. The tubes composing the reheating surface, the pipe line leading back to the turbine and the turbine blades are the parts that must be able to stand the high reheat temperature.

Combination of a gas reheater and a live-steam reheater may afford the best solution for plants using a throttle pressure of 1200 lb. per sq. in. or more and a temperature of about 750 deg. F. This keeps the maximum steam temperature down to a safe value and involves no great complexity of apparatus. The location of a live-steam reheater near the turbine reduces the length of the low-pressure piping to a negligible figure but the condensation from this reheater should be returned to the boiler and, unless the reheater is located above the boiler, this liquid must be handled by a special pump designed for a relatively small volume of water at high pressure and temperature.

High Superheat

On the other hand, if the temperature of the steam at the throttle can be successfully used at about 1000 deg. F., then with only one reheating to this temperature there will be only a little moisture formed in the turbine even with the throttle pressures as high as 2500 lb. per sq. in. Thus it is apparent why so much work is being done in Europe and America to develop materials that will stand up successfully under continuous operation at high pressure and temperature. At present the outlook seems encouraging, so it may be only a few years until many of our big power plants are operating successfully with red hot pipe lines. It sounds a bit uncanny to some of us now to think of such pipe lines sustaining a pressure of 2000 lb. per sq. in. or more but indications point that way. We know what we need to secure good thermal performance and with lots of effort spent in developing suitable materials the chances are favorable that we shall succeed.

Use of Exhaust Heat

After leaving the turbine, the steam that has not been bled for some purpose usually passes to a condenser where it gives up from two to three times as much energy as was delivered to the shaft of the turbine. The circulating water of the condenser absorbs this enormous amount of energy and delivers it to some river, lake or sea where it serves no useful purpose. The energy given to the circulating water constitutes the biggest thermal loss in a central station and also generally the most dif-

ficult one to overcome because this energy is unavailable for conversion into mechanical form, but can be utilized only as heat absorbed by a body at relatively low temperature.

Assuming first, that there is no chance to use the heat that may be obtained from the exhaust steam, then the central station needs a good condenser to maintain a low exhaust pressure and thereby secure much more work from each pound of steam passing through the turbine than if the exhaust were at atmospheric pressure. In maintaining this low exhaust pressure, many precautions must be taken to prevent leakage of air into the exhaust steam line, leakage of circulating water into the steam space and fouling of the condenser tubes with accumulations of various materials that reduces the rate of heat transmission from the steam to the circulating water. This accumulation takes a variety of forms, depending upon the kind of circulating water used and much ingenuity is often shown by the operating departments of different plants in maintaining clean condensers under adverse circumstances. An example of this kind is the use of chlorine in the circulating water at the Kearny station in New Jersey as recently reported to the Metropolitan Section of the American Society of Mechanical Engineers by Frost and Rippe.

Next, assuming that a central station is so located that there may be a chance to utilize, for a large part of the year, some or all of the exhaust steam for various heating purposes, the whole question concerning exhaust pressure, size of condenser and amount of circulating water required becomes quite different. The two possibilities of using exhaust steam from a central station at such pressures as may be needed are found in industrial plants and in district heating. Many industrial plants now generate all the electrical energy they need at a low cost because so much of their steam equipment is essential to supply their requirements for heat, unless it can be furnished by a central station.

If central stations adopt higher and higher pressures, as they probably will, the use of exhaust steam for district heating becomes more and more attractive in a large number of cities in this country. This method of heating generally involves a variety of questions, some of which, unfortunately, must be answered by petty politicians, while others can be answered only by a thorough engineering study of the entire problem existing in a particular locality. Increasing use of high-pressure steam, however, makes the question of how to use large quantities of exhaust steam from central power stations economically a live one that engineers may now profitably reconsider most carefully.

Even though waste of energy in modern steam stations has been much reduced when compared with those of ten years ago, the near future appears to offer unusual opportunities for additional improvements that are economically sound.

Saving Heat in Steam Piping Systems

DETERMINATION OF ECONOMICAL THICKNESS OF INSULATION. DRAINAGE OF CONDENSATE. IMPORTANCE OF DRY STEAM

AT PRESENT, there are probably few high-temperature steam lines left uncovered, as engineers in general realize the large heat loss from all uncovered steam using equipment. Many fittings and valves, however, are left uncovered, sometimes to provide easy access and sometimes from failure to realize that they are radiating heat just like the steam lines. Exactly how much they radiate is hard to determine. Careful tests by R. H. Heilman show that a 10-in. steam line at 700 deg. loses 82 per cent of its heat if not insulated. He suggests, therefore, that total loss from valves and fittings per unit area be assumed the same as for 18-in. pipe at corresponding temperature.

In the table are given the ratios of the value of the last increment of heat at the top of the temperature range to the value for the average of the range and it will be seen that this top increment of heat has a value between 50 and 100 per cent higher than that for the average. It is evident, says McMillan, that the effectiveness of this last increment of heat must be greater than that of the average because the average is penalized by low effectiveness of the first increment of heat added in the cycle; the first increment of heat in the cycle can do useful work only when the high-temperature increments have been added.

In the second part of the table is given the dollars loss per square foot per year from bare surfaces. As an illustration of what this may mean, in case of superheated steam pipe the per cent of surface left bare is usually quite small but, because of the higher temperatures and the greater value of the heat, the losses from such small areas may be much greater than would at first glance appear likely. For example, from one square foot of bare surface at 700 deg. F., the value of heat being 30 cents for 1,000,000 B.t.u., the loss is $9.30

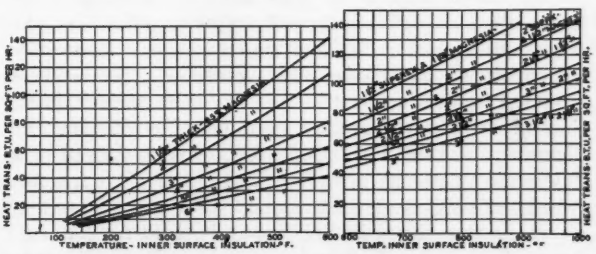


FIG. 1. HEAT TRANSMISSION THROUGH VARIOUS THICKNESSES OF INSULATION

per yr. If the steam pressure is 300 lb. absolute, reference to the table shows that the ratio of the high potential increment for power generating purposes is 1.54 times the average value, therefore the actual loss is $9.30 times 1.54 or $14.32 per sq. ft. per year.

Circulation of air over the surfaces greatly increases the loss, an air velocity of 10 mi. per hr. at least doubling the loss from bare surfaces while for insulated surfaces this increase, because of the less conductivity from the insulation to the air, will be only 10 per cent.

Figure 1 shows the heat losses that may be expected with various thickness of typical insulating material and at various temperatures. Insulation practice in connec-

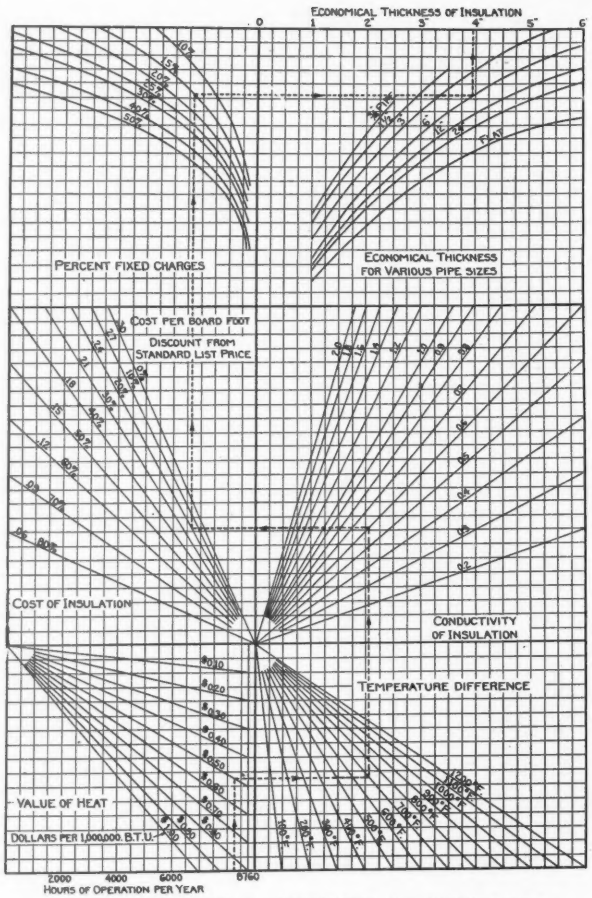


FIG. 2. ECONOMICAL THICKNESS OF INSULATION

tion with boiler drums, heads and other exposed portions of the shell, feedwater heaters and other auxiliary equipment is standardized and has been noted above. A notable exception is the insulation against heat losses of tube headers of water tube boilers. Perhaps these are not considered as exposed surfaces because of the doors which shut them from view but these doors offer comparatively little resistance to heat flow. While losses from the headers are less than if the doors were omitted, they are still much greater than need be. Lining the doors with suitable insulation provides resistance to heat flow many times as great as that of the air space between the headers and the doors.

While the curves in Fig. 1 may be used for flat surfaces of the boiler (not boiler settings) they will apply with reasonable accuracy to auxiliary equipment surfaces.

Figure 2 gives in graphical form the results of a

HEAT VALUE RATIOS AND ANNUAL LOSS

Steam Temp. Deg. F.	Heat Value Ratio at Various Temperatures to Average Value Steam Press., lb., abs. 40	100	300	600	Annual Loss per Sq.ft. in Dollars Steam Cost per 1,000,000 cts. 20	30	40	50	60
200					0.50	0.70	0.90	1.20	1.65
300	1.22				1.10	1.70	2.15	2.70	3.30
400	1.59	1.32			1.90	2.85	3.80	4.75	5.75
500	1.86	1.44	1.28	1.18	3.05	4.50	5.85	7.50	8.90
600	2.02	1.61	1.43	1.32	4.40	6.55	8.75	11.15	13.20
700	2.14	1.82	1.54	1.42	6.20	9.20	12.40		
800	2.21	1.90	1.63	1.51	8.30	12.65			
900	2.23	1.93	1.68	1.56					
1000	2.24	1.96	1.71	1.59					

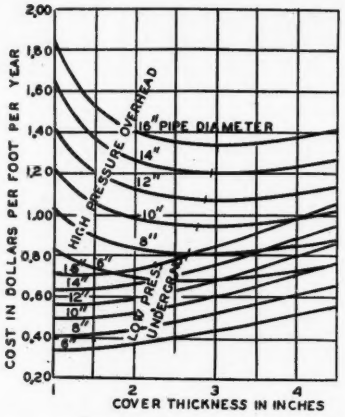


FIG. 3. COST OF INSULATION FOR VARIOUS THICKNESSES; MATERIAL OF HIGH FIXED CHARGES AND LOW CONDUCTIVITY

method developed by McMillan and recalculated with practically identical results by Heilman for the determination of economical thickness of insulation. Factors involved are all indicated on the chart. For continuous operation, there will be 8760 hr. a year. The value of heat in dollars for one million B.t.u. will not necessarily be the average cost of heat but its value as determined from the table. The temperature difference is the temperature of the inside of the equipment insulated minus the temperature of the surrounding air. It should be noted in this connection that if there is a considerable resistance to heat flow other than that offered by the insulation, as in the case of insulation on the brick furnace walls, correction must be made for the effect of these other heat resistances.

Conductivity of insulation is in B.t.u. per square foot per degree temperature difference per hr., for one inch thickness. The cost of insulation is given as a per cent discount from the standard list and also to provide for material whose costs are not figured in terms of discount the costs per square foot one inch thick are marked on the lines. Fixed charges are usually 15 per cent in the classes of work under discussion here.

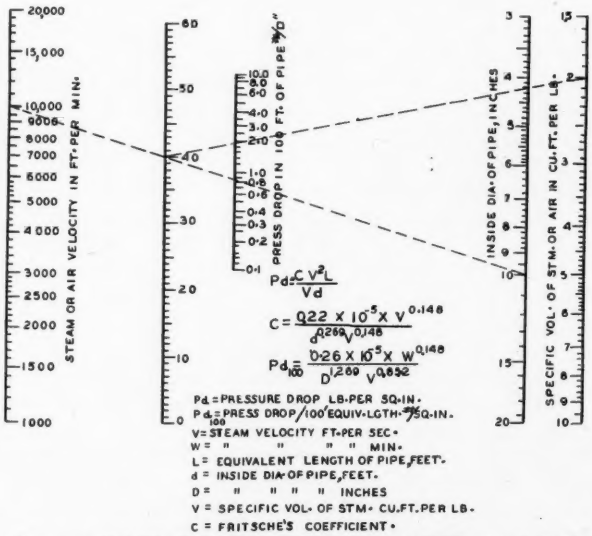

STEAM OR AIR VELOCITY IN FT. PER MIN.
PRESS DROP IN 100 FT. OF PIPE
INSIDE DIA. OF PIPE, IN INCHES
SPECIFIC VOL. OF STM. OR AIR IN CU. FT. PER LB.
Pd = C V² L / Vd
C = 0.22 × 10⁻⁵ × V^0.148 / d^1.269 V^0.148
Pd/100 = 0.26 × 10⁻⁵ × W^0.148 / D^1.269 V^0.852
Pd = PRESSURE DROP LB. PER SQ. IN.
Pd/100 = PRESS DROP/100' EQUIV. LGTH. PER SQ. IN.
V = STEAM VELOCITY FT. PER SEC.
W = " " " " MIN.
L = EQUIVALENT LENGTH OF PIPE, FEET.
d = INSIDE DIA. OF PIPE, FEET.
D = " " " " INCHES
V = SPECIFIC VOL. OF STM. CU. FT. PER LB.
C = FRITSCHE'S COEFFICIENT.

FIG. 4. CHART SHOWING PRESSURE LOSSES IN STEAM PIPING

Method of using the chart is indicated by the dotted line, which follows through to show that for 8250-hr. operation a year with the value of heat of 50 cents per 1,000,000 B.t.u., temperature difference 700 deg. F., conductivity of insulation 0.6, discount from standard list 20 per cent, fixed charges taken at 15 per cent and for a 6-in. pipe the economical insulation would be 3.9 in. thick. Of course the nearest commercial thickness, 4 in., is the one that should be used.

Figure 3 shows the cost of insulation for various thicknesses for material of low conductivity and high fixed charges.

Removal of Condensate from Pipe Lines

Pressure losses in pipe line are as given in Fig. 4. As radiation and pressure losses cause condensation of steam in pipe lines, this condensation must be removed as it might cause water hammer, erosion of valves and other troubles. Steam separators, drip pockets and traps are used to remove this condensation, which should be returned to the boiler feedwater system, if possible.

Non-return traps of various types, such as the bucket, float, tilting and thermostatic are used for returning condensate from steam lines carrying either high pressure or exhaust steam. Such traps should be insulated and properly vented. Several types of traps incorporate in their construction means for automatically venting the air at the same time they discharge condensate. Return traps discharge condensate directly into the boiler. These traps are either of the tilting type or of the type using a pilot valve to admit high pressure steam to discharge the condensate. This pilot valve is opened by a mechanism actuated by the rising level of condensate in the trap body.

The steam piping system should deliver dry, clean steam to engines and turbines and to process machinery where the steam is to mix directly with other materials. Slugs of water passing to prime movers may cause breakage of engine cylinder heads or erosion and breakage of turbine blades. Besides this, water carried by steam often carries solids with it in solution which are either deposited on turbine blades or cause erosion on them. For example, with a 1000-hp. boiler operating at 400 per cent of rating, the boiler concentration might be 100 grains per gallon. If the steam contained 2 per cent of moisture in a month it would carry with it approximately 200,000 gal. of water which would contain about 2900 lb. of solids in solution.

Various types of steam purifiers and separators are available for this work. To purify the steam as it leaves the boiler, a steam purifier can be installed between boiler drum and superheater inlet, or inside the boiler drum, thus preventing accumulation of deposits in the superheater, besides insuring clean steam in the lines. Other types of moisture separators can be installed in the lines, especially just ahead of steam using apparatus. Properly insulated and discharging condensate by means of traps to return lines leading back to feedwater heaters and evaporators, they produce worth-while savings of heat. On exhaust steam lines leading to heaters or process equipment, oil separators should be used.

Superheating of the steam can be resorted to, as discussed above, to prevent steam line losses.

Efficient Prime Movers Conserve Heat

High Temperatures, High Pressures, Extraction and Good Loading Factors to Be Considered

TWO PROPERTIES of steam must be considered when its efficient utilization is contemplated. Not only its heat content in heat units but its entropy or heat head must be used to advantage.

When considering the potential power of water, the weight in pounds and its elevation in feet above a given datum are taken into account. Obviously a cubic foot of water in the tailrace weighs just as much as a cubic foot of water in the forbay, perhaps 100 ft. above, but it is useless for power generating purposes. Similarly, a pound of steam at 212 deg. F. may have just as many B.t.u.'s as a pound of steam at 500 deg. F. but its potential power value is much less.

With water, the zero datum beyond which no power can be generated is sea level while, with steam, the zero datum is taken as 32 deg. F. although practically the lower limit is that temperature corresponding to about 29 in. of vacuum or around 80 deg. F.

As practiced today, the upper temperature range is about 750 deg. F. although a few plants have ventured above this. In pressures 400 to 600 lb. per sq. in. for industrial service are still considered rather high although plants of 800 and 1000 lb. are in service and one 1800-lb. pressure plant is under construction. In the central station class, 1200 lb. pressure at the throttle is the maximum in service in this country.

The importance of high temperatures from the standpoint of power generation is well shown by Figs. 1 and 2. The first is drawn for saturated steam and shows the power that would be generated in kilowatt-hours by an ideal engine working between definite initial and final pressures.

For instance, 150 lb. gage steam expanded to 10 lb. gage will give about 42 kw. per hr. per thousand pounds of steam; 300-lb. steam expanded to the same pressure will give about 55 kw-hr. per thousand pounds while 600-lb. steam will give about 73 kw-hr. This, therefore, is one way of balancing the heat and power load in a plant, that is increasing the temperature range by higher initial pressures.

Superheating Adds to Value of Steam for Power Purposes

A second method is by increasing the temperature range of the steam by superheating. A chart for calculating the power output of an ideal engine using superheated steam is given in Fig. 2. Thermally 200 lb. gage steam superheated 100 deg. F. has the same heat content and heat head as saturated steam. For instance, 25-lb. steam superheated 40 deg. F. has the same heat content as 108-lb. saturated steam but with the added advantage that a prime mover can utilize the

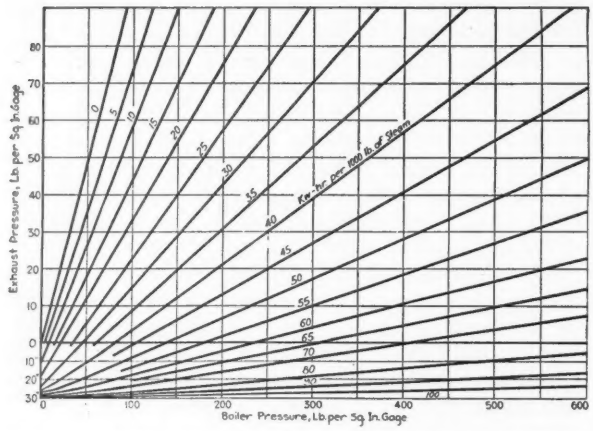


FIG. 1. POWER DEVELOPED BY AN IDEAL ENGINE USING SATURATED STEAM

superheated steam more efficiently. (For further details of these charts, see article by R. V. Kleinschmidt, Power Plant Engineering, p. 469, April 15, 1929.)

An actual engine or turbine will not develop as much power as shown by the curves. Figures so obtained must be multiplied by the Rankine cycle ratio of the engine or turbine. Small turbines will run from 40 to 65 per cent while turbines above 1000 kw. will range from 50 to 80 per cent. Engines will run from 70 to 85 per cent.

An efficient engine is, however, not the whole story. At best, even an ideal engine working between 600 lb., 750 deg. F. and 29 in. of mercury would be able to utilize but about 38 per cent of the heat of the steam while the balance would be exhausted to the condenser. Utilization of this exhaust heat is what determines the thermal efficiency of the station.

For instance, if all of the exhaust steam can be used in the process or for heating, practically all the heat of the exhaust steam can be reclaimed. The balancing of the power load and steam load so that no heat is lost in condensing water or to atmosphere is the job of the modern industrial power plant engineer. The central station engineer is interested in reducing the condenser loss to a minimum.

If, instead of steam, large amounts of hot water are required for process work, it may be best to use the condenser as a water heater and operate the condenser at a higher vacuum than would ordinarily be done; that is, sacrifice some of the power in order to avoid heat rejection in condenser water.

Up to a certain point, depending upon the initial water temperature and the rise required, this single stage heating is sufficient. In general, however, double stage heating with the second stage using bled steam at about the final water temperature will prove to be most satisfactory. Figure 3 represents the best condenser vacuum for two-stage heating between certain limits.

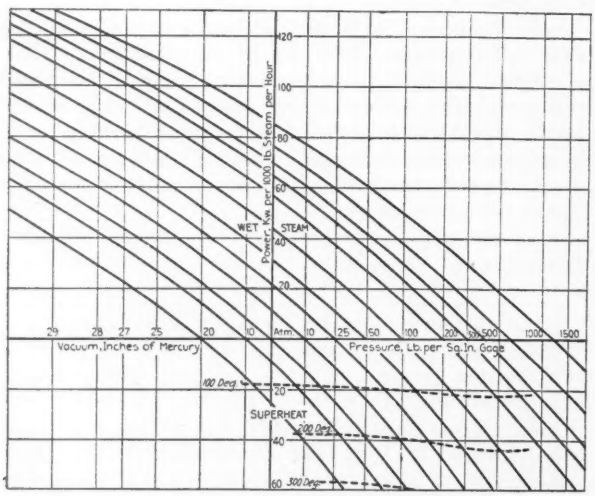


FIG. 2. POWER DEVELOPED BY AN IDEAL ENGINE USING SUPERHEATED STEAM

Condenser Loss Decreased by Bleeding

When warm water is not required and power and heat loads cannot be balanced, bleeding of steam can be

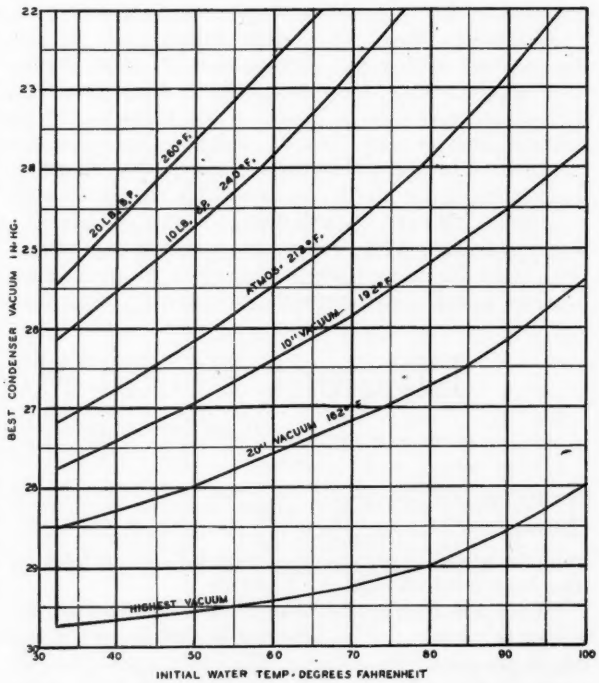


FIG. 3. BEST CONDENSER VACUUM FOR TWO-STAGE WATER HEATING, USING CONDENSER AS FIRST HEATER

resorted to. Each pound of steam bled reduces the condenser loss by a certain amount, roughly 950 B.t.u. per lb. It is, in effect, the same as operating two machines, one operating against a back pressure and generating sufficient power to meet the exhaust steam demands, the other operating condensing to carry the additional power load.

Both of these functions are carried on by one bleeder type machine automatically and with the added efficiency of the larger machine. Engines are sometimes arranged so that steam can be bled from the receiver or one end operated condensing and the other non-condensing. Some types of vertical unaflow engines are arranged so that some of the cylinders can operate condensing and others non-condensing. In central stations, bled steam is always used for feedwater heating

and for evaporator service, some of the latter high-pressure installations bleeding as much as 30 per cent of the steam flow to the throttle.

Another feature of central station practice is the use of reheating, that is partially expanding the steam in one element of a turbine and exhausting it to be reheated or resuperheated to, or nearly to, the initial temperature. For instance, at Deepwater station, 1200-lb. steam at 725 deg. F. is expanded to 400 lb. in the high pressure turbine and then reheated at this pressure to 750 deg. F. where it expands to condenser pressure in the low-pressure turbine.

In effect, the high-pressure turbine operates as a non-condensing turbine with no exhaust steam loss. At State Line, the steam is reheated in steam reheaters at about 73 lb. absolute. The initial conditions are 615 lb., 725 deg. F. so that the high-pressure turbine generates approximately twice as much power per pound of steam as at Deepwater but reheating can be carried only to 500 deg. F., so that the expansion range of the low-pressure machine is much more limited.

Automatic Temperature Control Used

Both gas and steam reheaters are in use, the former being of the convection or radiant type, similar to but much larger than superheaters while the second are steam-to-steam heat exchangers. Some new stations are using a combination of the two so as to give better automatic control. At high ratings when the boiler gases are hotter, the steam reheater uses less steam than at light loads when the boiler gases are relatively cool.

Utilization of the reheater condensate at the temperature of condensation, that is boiler pressure is extremely important and this condensate is commonly pumped into the boiler feed system behind the last heater so as to avoid the loss of heat head which would result if the water were drained to the low-pressure drip system.

Feedwater Heating by Bled Steam

ALTHOUGH THE PRACTICE of using extracted steam for feedwater heating in industrial as well as central stations is widely practiced, no universal standard practice has been developed for determining the best pressures or number of stages to use.

In Fig. 1 is shown the effect of heater location on the heat consumption of a turbine for the steam conditions given and with four stage heating. Maximum efficiency is obtained when equal amounts of steam are bled to each heater. It also shows, however, that when 15,560 lb. are bled to the highest heater and only 7530 lb. to the lowest heater the heat consumption is affected only about 0.4 per cent, so that considerable latitude can be used in heater location without materially affecting the results.

Final feedwater temperature for various numbers of heaters and for different pressures are given in Fig. 2. Inasmuch as the final temperature of the water is a measure of the heat reclaimed from the condenser, it is an indication of the gain in efficiency due to stage heating. At low pressures, four stages and at high pressures, five stages are considered about the maximum number at present because beyond this number the increment gain per heater decreases. Increased coal costs will raise the economical number of stages to use.

For extraction service, the usual heater is of the closed type, although open extraction heaters and deaerating heaters are used to meet specific conditions. When makeup is not introduced into the condenser hotwell, some form of deaerator is advisable to guard against corrosion from oxygen and carbon dioxide.

Deaerating heaters are built in a number of types, shapes and sizes, the operation in general consisting of

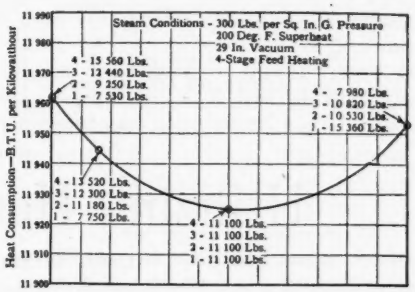

Steam Conditions - 300 Lbs. per Sq. In. G. Pressure
200 Deg. F. Superheat
29 In. Vacuum
4-Stage Feed Heating
Heat Consumption—B.T.U. per Kilowatthour
4 - 15 560 Lbs.
3 - 12 440 Lbs.
2 - 9 250 Lbs.
1 - 7 530 Lbs.
4 - 7 980 Lbs.
3 - 10 820 Lbs.
2 - 10 530 Lbs.
1 - 15 360 Lbs.
4 - 13 520 Lbs.
3 - 12 300 Lbs.
2 - 11 180 Lbs.
1 - 7 750 Lbs.
4 - 11 100 Lbs.
3 - 11 100 Lbs.
2 - 11 100 Lbs.
1 - 11 100 Lbs.

FIG. 1. LOWEST HEAT CONSUMPTION WHEN EQUAL AMOUNTS OF STEAM ARE BLED TO EACH HEATER

heating the water first either in an open or closed heater, and then flashing it into a second chamber at the same or a slightly lower temperature.

Gases dissolved in the water are liberated and vented from the heater, either to the atmosphere, if the heater is operating around 210 deg. F., or through a vacuum pump of some kind if the heater is operating under a vacuum. The usual practice today is to use the deaerator at about atmospheric pressure. Loss of heat and steam through the vent is prevented by a small surface condenser known as a vent condenser. Cool water on the way to the heater first passes through this condenser. When using the condenser as a deaerator close attention must be paid to condenser leakage and gland leakage around the condensate pump shafts.

Maximum gains from bleeding come in the lower pressure range, that is, when the steam is bled from the turbine as near condenser pressure as possible. With closed heaters, there is a necessary temperature differential between the steam bled and the water being heated. This difference is usually about 6 deg. F. in commercial heaters and six degrees in the lower pressure

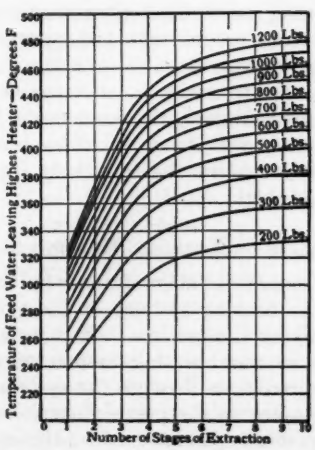


FIG. 2. ABOVE FOUR, GAIN PER HEATER DECREASES

range is considerable. For this reason, open heaters, similar to a jet or barometric condenser, are sometimes used because the water can be heated to practically the same temperature as the steam which is heating it. A separate pump is required however.

Heaters Piped in Series

Closed heaters as commonly used consist of a bundle of tubes in a shell similar in construction to a condenser. Steam surrounds the tubes and the feedwater is pumped through the tubes, a number of heaters usually being used in series, each heater raising the temperature a certain amount.

Bleed heaters always work on what is known as the induction principle, that is, steam from the bleed connection flows to the heater shell as condensation takes place and there is no flow of steam across the tubes, except as it must flow over the top tubes to get to the bottom of the tube bundle.

Steam used in heating condenses and collects at the bottom of the heater from which it is collected in a number of ways. The most thermally efficient is to pump the condensate into the feedline ahead of the heater without loss of heat head. This involves a drain pump for each heater, however.

The more common way is to drain the highest pressure heater to the next lower one through a trap, goose neck seal or orifice, to the next lower heater and so on to the lowest pressure heater from which the combined condensate is pumped to the feedline ahead of the heater.

Utilizing Heat of Exhaust Steam

Vacuum Systems and Unit Heaters for Building Heating. Types of Open Feedwater Heaters

ECONOMY of using exhaust steam for heating purposes, either in building heating or process work, is evident when it is remembered that seldom does more than 7 to 10 per cent of the heat above 32 deg. supplied

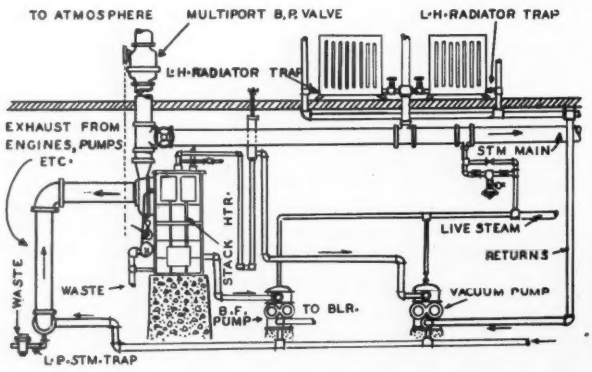


FIG. 1. VACUUM SYSTEM APPLIED TO EXHAUST STEAM HEATING

the average noncondensing prime mover appear as work. At 100 lb. gage pressure, the heat in the steam would be about 1190 B.t.u. per lb. and at exhaust pressure of 15 lb. absolute there would still be approximately 1150 B.t.u. in the steam. At this pressure, however, the steam would be just ready to condense and if it were passed through radiators, the condensate leaving them at 200 deg., about 980 B.t.u. would be extracted. This is about 80 per cent of the total heat supplied to the steam above 32 deg.

Principles of Exhaust Heating Systems

Exhaust steam, suitably cleaned by oil separators, can be used in heating systems of the types shown in the accompanying illustrations. It is usually necessary to employ a vacuum heating system of some sort to insure good circulation through the system and prevent high back pressure on the prime mover.

In such vacuum systems, each radiator, blast coil or unit heater is equipped with a vacuum valve or a trap, usually of thermostatic type, on its return end. This is to allow air and condensate to pass through but no steam. To handle this water and air, a vacuum pump on the return line maintains several inches of vacuum in the return line so that the valves can discharge freely.

These provisions assure positive circulation in the system when steam mains and branches have been properly designed. Pressure loss in these lines is in most cases figured as 1 oz. per 100 ft., a value that has given good results. A live steam bypass, equipped with a reducing valve, usually connects the exhaust main with a high-pressure steam line to give automatically a supply of live steam if the exhaust should be insufficient.

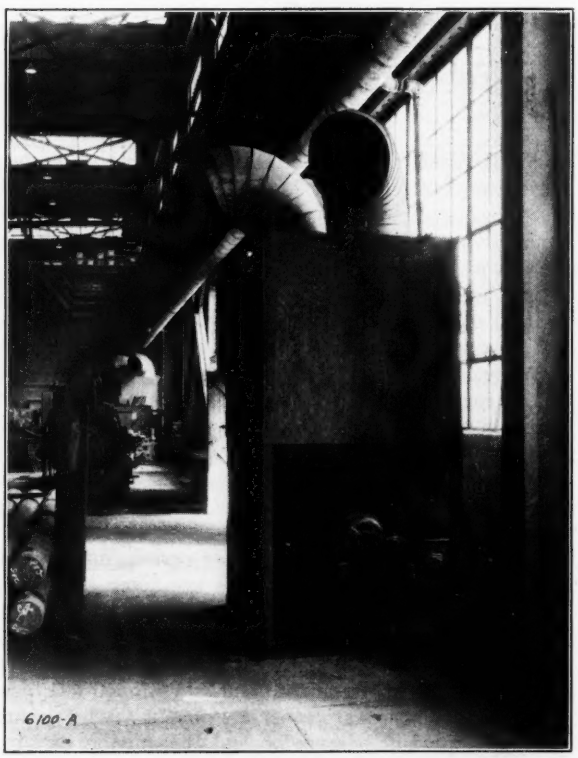


FIG. 2. AN INSTALLATION OF FLOOR TYPE UNIT HEATERS

FIG. 3. UNIT HEATERS SUSPENDED FROM CEILING IN A SILK MILL

Figure 1 shows the elements of a typical exhaust steam heating system.

Hot-water heating systems have been installed to use exhaust steam, when the temperature, pressure and amount of the exhaust are sufficient to heat the required quantity of water to the temperature necessary. For various outdoor temperatures, the water in the system usually varies from 230 deg. at —20 deg. outdoors to about 100 deg. for 60 deg. outdoors.

Large air conditioning systems often employ exhaust steam in the blast coils over which the fans blow air. Design of these is governed by the same general principles that govern radiator systems except that the air velocity hastens heat transfer. Proper attention to drips, insulation and return of condensate promotes economy in such systems.

Unit Heaters

Blowing of air over heated coils in large central systems has led to the development of the unit heater. Here the heating coil and a fan to blow air over it are combined in small units that can be located conveniently in the room to be heated, discharging the heated air into the enclosure. Some types of these heaters also incorporated air filters for cleaning the air and others have humidifying devices in them.

Unit heaters are made to operate on hot water, vacuum or vapor steam systems or with steam at any pressure up to 200 lb. or more. Thermostatic controls are often applied to them to control fan speed from room temperature, thus decreasing power consumption of the fan. Suitable traps and return lines lead the condensate back to the feedwater heater or storage hotwell. Figures 2 and 3 show typical unit heater installation.

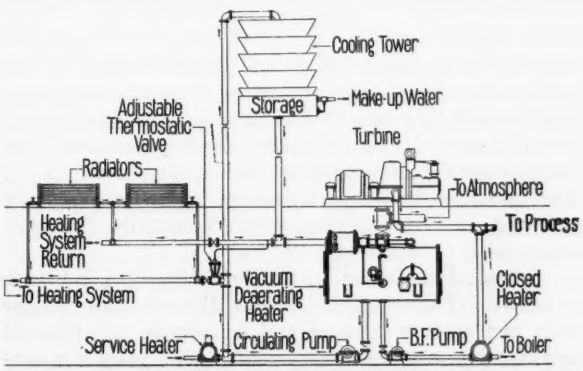


FIG. 4. DEAERATING HEATER USING EXHAUST FROM TURBINE (ACTION MUCH LIKE THAT OF JET CONDENSER BUT VACUUM VARIABLE)

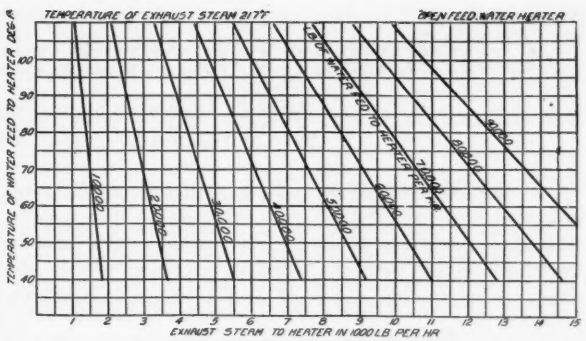

TEMPERATURE OF EXHAUST STEAM 21.7°
OPEN FEED WATER HEATER
TEMPERATURE OF WATER FEED TO HEATER DEG F
EXHAUST STEAM TO HEATER IN 1000 LB PER HR

FIG. 5. AMOUNT OF EXHAUST STEAM REQUIRED TO HEAT WATER IN OPEN FEEDWATER HEATER

Feedwater Heaters Taking Exhaust Steam

Exhaust steam for heating feedwater is usually employed in modern plants in open heaters, often of the deaerating type. Heating with extracted steam, as practiced in many large plants, is discussed in a previous article. As previously pointed out, if exhaust steam heats the feedwater, a saving of about one per cent of the fuel is made for each 11 deg. F. the water is heated. Probably the simplest arrangement of an open feedwater heater is where the heater is taking exhaust steam from auxiliary equipment or from a non-condensing prime mover. Figure 4 shows an extremely flexible arrangement incorporating a vacuum deaerating heater receiving turbine exhaust steam. Some of the water is drawn out for boiler feed, heated by extracted steam. Some of it goes to a hot-water heating system and any excess heat is dissipated by a cooling tower.

Open heaters are usually arranged to shower the water through the steam and to make it flow over trays in an atmosphere of steam. They can be of horizontal or vertical types and they usually incorporate storage space. Sometimes they include oil separators and filters and often water measuring devices. For storage of hot water, they are usually made with a heating coil immersed in a large body of the water, so that heat will be stored up. They can be designed for vacuum and back pressure operation. Deaerating heaters vent noncondensable gases through a vent condenser, often to the main condenser. If deaeration is at pressure below atmospheric, a steam jet exhauster may be used to exhaust the vent condenser, followed by a gleaner heater for recovering exhauster steam.

Open feedwater heaters can be obtained to heat as much as 720,000 lb. of water an hour.

Power plant tests are usually made to determine the efficiency or capacity of a piece or combination of several pieces of equipment. The efficiency of a machine is the ratio of useful work delivered to the work or energy supplied. The limit of efficiency is obviously unity, the efficiency of a perfect machine.

Condenser Operation and Use of Condensate

FACTORS AFFECTING CONDENSER OPERATION. USE OF CONDENSATE AS FEEDWATER. HEAT SAVING BY USE OF COOLING WATER

AS A FACTOR affecting the overall station economy, the value of the condenser is becoming increasingly important not only to designing engineers but also to operators, since, with the possible exception of the furnaces, there are few pieces of equipment in the modern

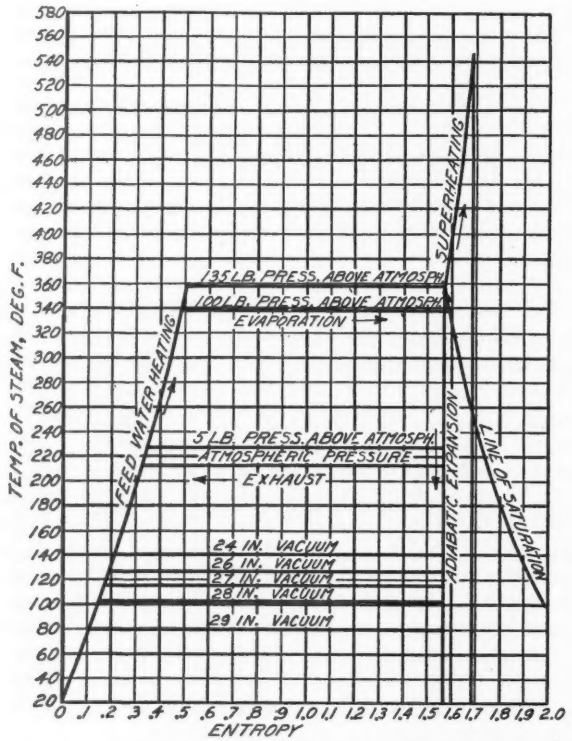


FIG. 1. ENTROPY DIAGRAM SHOWING RELATIVE VALUES OF WORK THEORETICALLY AVAILABLE AT DIFFERENT BACK PRESSURES

power station which reflect proper operation to a greater extent than the condenser. For the condenser can not be considered as a device in itself; rather, it must be considered in relation to the steam turbine or engine it serves, for the economy of the turbine or engine is directly dependent upon the performance of the condenser. More than this, in stations where more than one unit is installed, each unit must be considered in relation to the whole with fixed investment charges considered along with the operating costs.

While condensers are installed primarily for the purpose of decreasing the back pressure against which the turbine or engine is to operate, in modern plants the recovery of condensate for boiler feed purposes is almost of equal importance. With the extremely high capacities in use today, it is highly important that the feedwater be as free from scale forming impurities as possible and if it were not for the fact that a source of extremely pure water is available in the condensate from the condenser, the overall station economy would be considerably lower than it is today since practically the entire supply of boiler feedwater would have to be evaporated at a considerable expenditure of heat units.

In theory, at least, the higher the vacuum in a condenser the lower the water rate of the turbine or engine. This is shown in Fig. 1. Areas enclosed above and below the atmospheric line show theoretical work available from the heat in the steam for a machine working on the Rankine cycle. The importance of the condenser in the overall economy of the prime mover unit may be appreciated when it is noted on this diagram, that an increase of 35 lb. in the initial steam pressure in the neighborhood of 100 lb. adds less work than an increase in vacuum of 2 in. for the lower vacuums and less than that added by 1 in., when the vacuum is increased from 28 to 29 in.

This, it must be understood, is entirely theoretical. Practically, it is not feasible to operate condensers at vacuums below a definite maximum determined by the design of the plant or the type of prime mover. Most

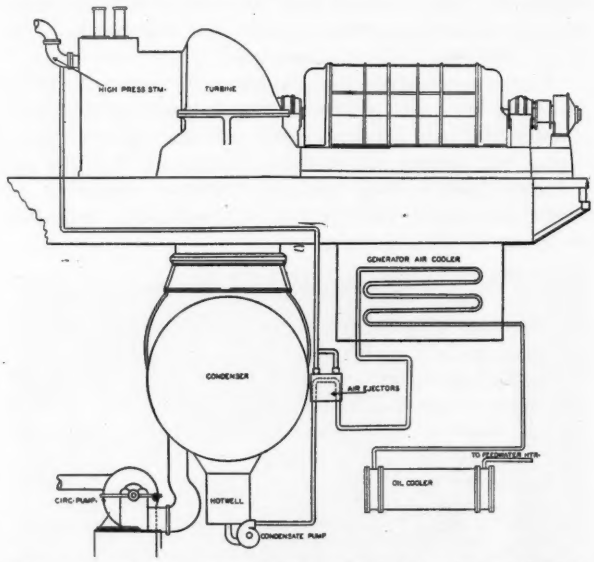


FIG. 2. TYPICAL CONDENSER INSTALLATION SHOWING USE OF CONDENSATE IN GENERATOR AIR COOLER AND OIL COOLER

engines are limited to 26 in. of vacuum because of the prohibitive cost of large cylinders necessary for operation beyond this point. Turbines, on the other hand, are designed for considerably higher vacuums, the largest units being designed for operation at 29 in. Turbines used in industrial plants are more commonly operated at 27 or 28 in., which is usually the most economical.

A typical condenser installation is depicted in Fig. 2. It consists of three main divisions, the condenser proper with the cooling surface and a suitable air removal apparatus to remove the noncondensable gases, the condensate system to remove the condensate from the bottom of the condenser shell or hotwell and the cir-

culating water system to absorb the heat of the condensed steam. This diagram shows a generator air cooler and an oil cooler, both of which use the condensate as the cooling medium.

This method of reclaiming some of the heat produced in the windings of the generator by passing the condensate from the condenser through the air cooler has been in use for a number of years and has proved quite effective. Due to the increased use of stage heating and the use of lower pressure steam for this purpose, the advantages of this method of cooling are less than they once were and for this reason it is not being used as much. Where generator air coolers are installed, it is now common practice to use the circulating water as the cooling medium.

In smaller plants where only one or two stages of reheat are used, this method of reclaiming the heat produced by the generator in the condensate possesses advantages not only in that it increases the thermal economy of the system but also conserves the use of raw water. This is of particular importance in plants where the raw water supply is limited.

Use of Condensate as Feedwater

Except for a few isolated cases, the use of condensate as feedwater is practically universal practice. As has been stated, the condensate from the condenser is exceptionally free from scale forming impurities and thus makes ideal boiler water. Furthermore, the heat remaining in the condensate reduces the amount of steam required to bring it up to boiler temperature.

Where the condensate is used as boiler feed, it is usually necessary to add a certain amount of makeup. In some cases, this makeup is taken from the condenser circulating water system on the discharge side of the condenser. While the amount of heat thus reclaimed is small, good condenser practice places the temperature rise of the circulating water about 10 deg. F., so where the amount of makeup is considerable, this heat recovery may be utilized at little or no expense.

The necessity of maintaining a high vacuum makes it imperative that a sufficient amount of circulating water at the proper temperature be supplied to the condenser. The correct amount of water for a particular installation is dependent upon a number of factors. Since the heat absorbed by the cooling water must be equal to that given up by the exhaust, neglecting radiation and leakage, the amount of cooling water may be determined as follows:

$$Q = H\ S \div (t_1 - t_0)\ 500$$

in which Q = quantity of circulating water in g.p.m.
H = B.t.u. per lb. of exhaust steam to be absorbed
S = pounds of exhaust steam per hr.
t_1 = temperature of circulating water, in.
t_0 = temperature of circulating water, out.

In the average plant, the heat in the exhaust steam amounts to from 925 to 1000 B.t.u. per lb. Assuming an average figure of say 950, and denoting the temperature rise of the cooling water $(t_1 - t_0)$ by T, the above formula reduces to

$$Q = 1.9\ S \div T.$$

Ordinarily, with a rise in circulating water temperature of about 10 deg., about 100 lb. of circulating water is required per lb. of steam. The amount of circulating water required increases rapidly with an increase in inlet water temperature and as the degree of vacuum required is increased. The relation between these factors is shown graphically in Fig. 3 which gives the amount of cooling water necessary for surface condensers.

Saving Heat by Use of Cooling Water

In some industrial plants where large quantities of warm water are used in manufacturing processes, it is often possible to utilize the heat of the circulating water. In a certain oil refinery, for instance, a large quantity of warm water was required for condensing and cooling the wax and lubricating oil streams from an oil still. Warm water is much more desirable for this purpose than cold water because cold water is likely to congeal the wax in the coils and cause plugging. By using the circulating water from the steam turbine condenser for this purpose, the expense of heating the water was

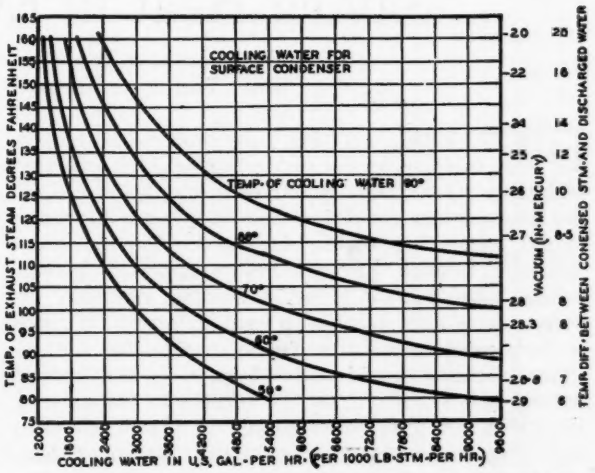
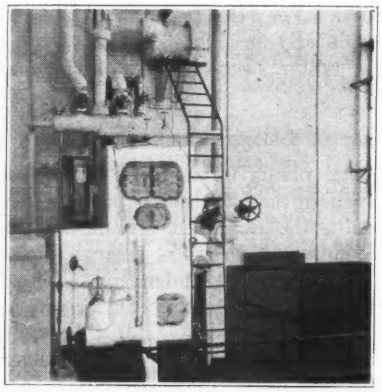

COOLING WATER FOR SURFACE CONDENSER
TEMP. OF COOLING WATER 90°
80°
70°
60°
50°
TEMP. OF EXHAUST STEAM DEGREES FAHRENHEIT
VACUUM (IN. MERCURY)
TEMP. DIFF. BETWEEN CONENSED STM. AND DISCHARGED WATER
COOLING WATER IN U.S. GAL. PER HR. (PER 1000 LB. STM. PER HR.)

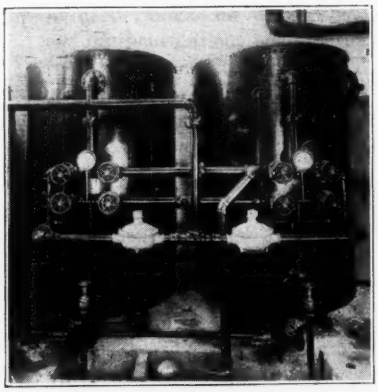
FIG. 3. COOLING WATER NECESSARY FOR SURFACE CONDENSERS

saved and what was perhaps even more important at this plant, the total quantity of water used was decreased. At this particular plant, the distance between the power plant and the river was considerable. In order to reduce the total quantity of circulating water pumped, the circulating water was used three times. Not only was it utilized in the main turbine condenser and for cooling the oil as already described, but before it was delivered to the turbine condenser, it performed a preliminary duty in cooling the condenser of two 100-t. absorption type refrigerating machines. In passing over the refrigerating condenser coils, the water picked up only sufficient heat to raise the temperature 5 deg. As the water was quite cold, this made little difference as to its effectiveness in the steam condenser.

In many cases, in the operation of surface condensers in winter the circulating water becomes too cold. Theoretically, of course, the colder the water, the better the vacuum, but in practice after the vacuum has reached the degree for which the system was designed, further cooling of the circulating water tends to chill the condensate to such an extent that the overall economy is reduced. In such instances, the water can often be recirculated with considerable advantage.



Heat Economy in Feedwater Systems



Saving Heat in Evaporator Systems

EVAPORATORS TO REDUCE BOILER CLEANING AND INCREASE HEAT TRANSFER. DEAERATORS FOR REDUCING CORROSION

DURING THE PAST few years, because of the general increase in the production of high pressure, high temperature steam at extremely high boiler ratings, the necessity for supplying absolutely pure feedwater to the boilers has greatly increased. The feedwater delivered to high pressure boilers operated at high ratings must contain no scale forming materials, not only because scale deposits in such boilers would result in frequent tube failures due to overheating, but the boiler efficiency would suffer because of the lowered rate of heat transfer from the furnace to the water in the tubes. A pure water supply in plants operating high pressure boilers, reduces the need for boiler cleaning, therefore reducing the outage time.

In order to produce such a supply of pure water, many plants, today, are using evaporators, which distill the entire makeup feedwater supply. The distillation of water, theoretically at least, effects the complete elimination of all solids or gases which the raw water contains. In practice with large scale operations such as take place in power plants this is seldom possible and the distillate obtained from evaporators usually contains a small amount of solids either in suspension or solution. This condition results from water being carried from the evaporator with the vapor as it is discharged from the apparatus. This small amount of solid material, however, is usually negligible and boilers using water of this kind can be operated at high ratings for periods of a year or more without the formation of any scale whatever. The value of evaporators in plants of this kind, therefore, is apparent.

Distilling plants or evaporators have long been used in marine work to supply pure makeup water from ocean water. Such independent type evaporator plants, using raw water as the condensing medium were developed before the consideration of distilled water for boiler feed makeup, and naturally this was the first type of plant used for makeup purposes. Such plants were expensive to operate and for this reason their use was confined to shipboard plants where it was imperative that a supply of pure makeup be provided. Cost was a secondary item. To reduce the heat losses of the independent type plant, multiple effect systems were resorted to, resulting in an increase in evaporative efficiency, but this method only partially eliminated the heat losses.

Such heat losses can be totally eliminated by using boiler feedwater as the condensing and absorbing medium for the evaporators. If this is done, practically all of the heat given up by the steam in evaporator coils is returned in the boiler feed to the boiler. Except for small radiation losses and small losses due to evaporator blowoff, distilled makeup water can be produced in this manner without expenditure of heat. Before we discuss further the economies of evaporation, the various types of systems available will be considered.

TYPES IN USE

Although evaporators for feedwater purposes are of comparatively recent development, several types of equipment are on the market. There are three general classifications: the submerged tube, the film and the flash type. These may be further classified according to the number of effects used, as single, double, triple or quadruple effect. Classification is made also with respect to the pressure of the steam supplied, that is, high pressure or low pressure evaporators indicating respectively evaporators supplied with live steam or exhaust steam. Further, evaporators may be classified as high-heat-level or low-heat-level evaporators, the former term indicating the utilization from the last effect for feedwater heating above 212 deg. F. and the latter, when the feedwater is heated by these vapors at a lower temperature.

Which of these various types of evaporators to use in any station depends largely upon the source of the heat utilized and upon the conditions of heat balance. In general, the two controlling factors are first, the available provision for utilizing the latent heat of the vapor discharged from the evaporator and second, the possi-

bility of utilizing steam which has performed a certain amount of useful work prior to its use in the evaporator coils.

In the design of any evaporator layout, the primary consideration is to eliminate as far as possible the heat losses due to the operation of the unit. Where considerable exhaust steam is available and the vapor may be employed economically to heat the boiler feedwater, a low heat level evaporator may be used. The unit may be a single effect evaporator, provided all the heat from the vapor may be absorbed in the boiler feedwater by the condensate from the main units. By this arrangement, all the heat from exhaust steam (except losses due to radiation and blowdown) will be absorbed and no losses will occur. In many cases, the vapor produced by a low heat level, single effect evaporator may be greater than can be absorbed for useful work at various loads. When this is the case, a multiple effect evaporator is warranted.

Evaporative Efficiency

The reason why a multiple effect evaporator is desirable in such case is that a multiple effect evaporator has a higher evaporative efficiency than a single effect evaporator. By evaporative efficiency is meant the number of pounds of distillate produced per pound of steam. Single effect evaporators, according to Powell, will deliver about 0.8 lb. of distillate per pound of steam, while a double effect system will yield approximately double this and a triple effect, three times this.

A multiple effect evaporator is an arrangement of single effect evaporators in series so that the vapor produced in one effect is utilized to heat and vaporize the water in the effect following it in series. The vapor coils of each effect serve as the condenser for the previous effect, the latent heat of the vapor of one effect thus serving to vaporize the liquid in the next effect.

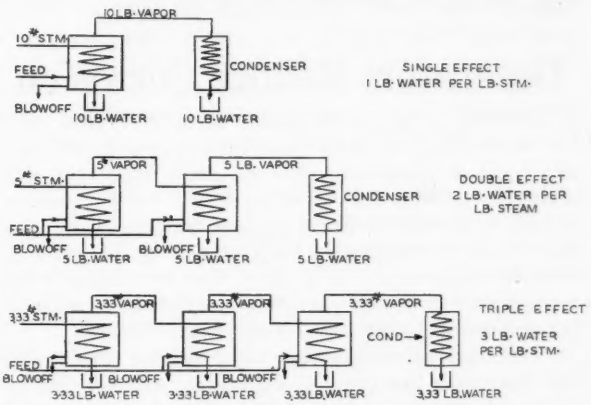
In the accompanying diagram, the differences in the evaporative efficiency of single, double and triple effect evaporating systems are indicated. In the upper arrangement, that is, the single effect, 10 lb. of steam is delivered to the evaporator resulting in the production of an equal amount of vapor which condenses into 10 lb. of water. The water condensed in the first coil cannot be considered as being a part of the output of the apparatus as this merely balances the steam supplied to the evaporator. Thus, this equipment, producing 10 lb. of water on 10 lb. of steam input, has an evaporation factor of 1 lb. of water per pound of steam.

In the double effect system, only 5 lb. of steam are supplied to the system. This, as may be noted, results in the production of a total of 10 lb. of water, the 5 lb. of water produced in the first evaporating coil being disregarded as in the previous case. Thus, this system produces 10 lb. of water for 5 lb. of steam, or 2 lb. of water per lb. of steam. From this it is evident that the evaporative efficiency of the double effect arrangement is just twice that of the single effect system.

The principle, it will be noted, is carried out still further in the lower diagram of the triple effect. Here, only 3.33 lb. of steam is delivered to the system. This 3.33 lb. of steam, however, produces 3 × 3.33 lb. or a total of 10 lb. of water, an evaporation of 3 lb. of water per lb. of steam. By adding further stages, quadruple, quintuple and even sextuple effect evaporators are produced, each with a corresponding increase in evaporative efficiency.

These illustrations are purely theoretical and in actual practice the ratios of water to steam are somewhat less. This is due not only to the heat losses in radiation and blowoff but also due to lower feed temperatures and to the temperature drop that must be allowed for in actual operation.

It might be construed from this discussion that the multiple effect evaporating system because of its higher evaporative efficiency would be the most desirable in all cases, but as has been intimated in the first part of this article, this is not true. The economic consideration of the number of effects to use for a particular plant is determined to a great extent by balancing the fixed and operating costs of the increasing number of effects against the utilization of heat released in condensers



DIAGRAMS OF SINGLE, DOUBLE AND TRIPLE EFFECT EVAPORATOR SYSTEMS, SHOWING INCREASE IN EVAPORATIVE EFFICIENCY WITH MULTIPLE EFFECTS

in the final effect under various load conditions of the station.

The evaporative efficiency is of no consequence in considering the thermal cost of distilled makeup water if the evaporator plant is so associated with the power plant heat balance that the output of the evaporators is condensed and absorbed by the boiler feed without power decrement. That is, it is of no importance in connection with so-called "associated evaporator plants" where the condensing medium is the boiler feed on its way to the boiler and where the evaporating plant is associated so as not to impair the intended heat balance of the plant.

The larger the number of effects, the less will be the heat to be absorbed by the boiler feed for a given amount of makeup. According to Joseph Price in a bulletin issued by The Griscom-Russell Co., if a large part of the power plant auxiliaries are electrically driven, and there is comparatively little exhaust steam available for use in boiler feed heating, and if the amount of makeup is less than about 10 per cent of the total feed, then the vapor from a single effect evaporator together with the drains from its coil, may be piped directly to an open type boiler feed heater, where it will be absorbed by the condensate from the main condenser, the resulting mixture being the correct amount of boiler feed at approximately 210 deg. F. If the makeup required is less than 5 per cent an appreciable

portion of the power plant auxiliaries may be steam driven and a single effect evaporating plant used.

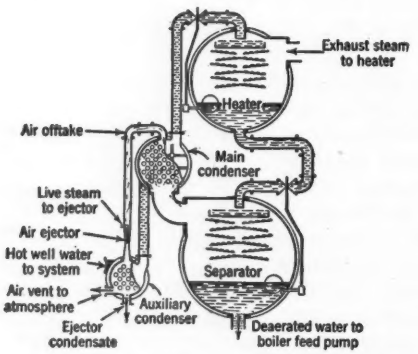
Effective Heat Transfer

In order to insure effective heat transfer in the operation of evaporators, it is necessary that the heating coils be kept free from scale. The scale is usually hard and dense and adheres tenaciously to the metal surfaces. It can usually be removed by suddenly changing the temperature of the metal coils, thus cracking off the incrustation by the expansion and contraction caused. Some of the scale usually remains on the tubes and for this reason it is necessary at intervals to remove the scale by mechanical or chemical means. In the case of film type evaporators, the scale may be removed by shutting down operation and putting the shell under partial vacuum. This causes the moisture in the scale next to the tubes to flash into steam, which exerts sufficient pressure to blow the scale off the tubes.

Deaerators Reduce Corrosion

CORROSION in power plants is costly. It is only within the past decade that the power-plant rodents, which eat so effectively into expensive apparatus and piping, have been discovered to be air, oxygen, carbon dioxide and other occluded gases carried by water and the method of eliminating them by boiling the water in deaerators provided. In a short time deaeration, from a previously unknown principle, has become a necessity for economical operation of high-pressure boilers.

Contributing factors that cause pitting of a boiler and feedwater line are: 1. Entraining excessive air by discharging pipes into hot wells and tanks without submerging the ends. 2. Feeding the water to the boiler through a closed heater without first passing it through an atmospheric deaerator. 3. Feeding water to a boiler from an open heater which has been improperly vented. 4. Feeding water that has absorbed excess carbon dioxide. When a boiler starts to pit, the water should be examined at once for oxygen and CO_2. Only in rare instances is electrolysis responsible for this trouble.



DIAGRAMMATIC REPRESENTATION OF SEPARATE TYPE OF DEAERATOR

Types of Deaerators

Deaerators are made in several styles, depending upon the nature of the operating conditions of the plant. One type employing separate heater and separator is illustrated diagrammatically. In this type, water from the main supply or hot well is passed through the auxiliary and main condensers, as it flows to the heater. Exhaust or bled steam, supplied to the heater produces the desired water temperature.

From the heater, the water passes to a separator which is under a pressure less than atmospheric. The vacuum is always great enough so that the temperature corresponding to the absolute pressure in the separator is less than that of the water, therefore the water in the separator is boiled violently and some vapor, together with the dissolved gases, is driven off.

Vapor and emitted gases pass to the main condenser where the vapor-condensed and the non-condensable gases are removed by a steam-actuated air ejector. The heat of the vapor and of the ejector exhaust is recovered by the incoming water as it passes through the deaerator condensers, so that the deaerator becomes a part of a regenerative feedwater heating system. Integral type deaerators are constructed with separator and condenser in one shell.

Open-Type Heaters Serve as Deaerators

Open-type feedwater heaters serve inherently as deaerators provided the water is heated to a temperature of above 155 deg. and the heater is properly vented. Care must be taken not to vent excessively, as over venting permits unnecessary loss of steam; too small a vent holds air in the heater and prevents the water from giving up all of its gases. There is no loss of heat by radiation from a deaerating heater. Even the heat in the steam used by the ejector or steam-jet air pump serving the deaerator, when the latter is operated under vacuum, is returned to the feedwater by condensing the exhaust from the air pump in a small surface condenser included in the feedwater circuit. In this type also, there is no drop between steam and final water temperatures. Considerable success has been obtained in Germany by passing the feedwater through filters filled with iron turnings which, becoming oxidized, remove the oxygen from the water. Such a filter must, however, have the turnings renewed frequently.

Cost of operating a deaerator is practically nothing. Operation is automatic and there is nothing to get out of order or that requires replacement.

Preheated air is instrumental in raising boiler efficiencies by increasing the furnace temperature, giving better combustion of fuel with less excess air. On grates, the flame is shortened and the coal burns out completely while, with pulverized coal, the flame is also shortened and ignition with wet or low volatile coal improved. Shortening the flame is instrumental both in reducing slag on the boiler tubes and smoke in the exit gases. Higher furnace temperatures increase the heat transfer by radiation.

Where furnace changes can be made to give the necessary heat releases, air heaters can often be used to advantage for getting higher boiler ratings without entirely rebuilding the plant. They require relatively little space and are effective in recovering the heat which would otherwise be lost in the exit gases.

Flywheels are used on engines to give steadiness of rotative speed.

Reducing Friction Losses

ALINEMENT, UPKEEP AND LUBRICATION OF BEARINGS. BELT AND GEAR FRICTION

MISALINEMENT of bearings is probably the cause of most unnecessary friction in power plant equipment. Misalinement tends to distort a bearing and journal; bearing pressure is no longer equally distributed and high local pressures, for which the bearing was not designed, are exerted upon limited portions, thus causing the oil film to be broken, resulting in increased friction, heating, and seizure. This series of actions causes extreme wear of the bearing and perhaps of the journal, still further increasing the friction.

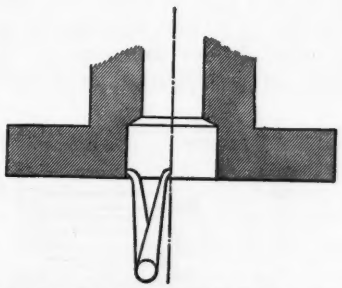


FIG. 1. METHOD OF LINING UP GLAND

Poor lubrication, due either to the lubricant or to the method used to apply it, is another principal source of friction in power plant equipment.

All equipment should be carefully alined and leveled before being fastened permanently. Provision for the former is made by use of boxes or pipes placed around the foundation bolts before the concrete is poured thus permitting the machine to be shifted on the foundation during the setting, after which the spaces around the bolts are filled with cement grout to fix permanently the positions of these bolts.

ENGINE ALINEMENT

Alinement of an engine is best accomplished by stretching a fine piano wire through the cylinder and guides after the head, piston, piston rod and crosshead have been removed. This string is calipered at selected points in the counterbore and on the guide by means of a stick of wood with pins in the ends. A flag consisting of a small piece of paper attached to the wire will indicate by its motion the merest touch by the caliper. In order to attach the wire at the head end of the cylinder, a four-armed wooden spider is fastened temporarily to the head. The line passing through the gland may be calipered as shown in Fig. 1. Squaring the engine shaft to the centerline of the engine is accomplished as indicated in Fig. 2 by rotating the shaft from position A to position B and calipering the string to insure that it lies exactly in the center of the crankpin in both positions.

Many of the difficulties that arise in steam turbine operation, such as hot or worn bearings, leaky shaft packing, vibration and broken shafts caused by crystallization, especially in high speed machines, will be found due, if traced to their source, to bad alinement of shafts. Even though the bed plate is of ample cross-section, it may be sprung in shipment, or warped in course of erection by being bolted down incorrectly. Misalinement may be caused after erection by faulty foundation, inadequate doweling, heavy piping without proper provision for expansion or proper supports to relieve the turbine from strain. For these reasons, level should be checked occasionally by use of good level of at least 8 in. in length set on a long straightedge. In use, the level should be reversed for checking. Alinement may be checked by stretching a fine wire through the bearings in a manner similar to that described for reciprocating engines.

In another method commonly used, where the shaft is coupled with a flanged coupling, the flanges are first wedged apart after the bolts have been removed, then a steel feeler wedge is entered between the flanges at different points around the edges. If the wedge enters exactly the same distance in every case, the shaft is in line. Opposite points of the flange should be checked in pairs.

RECLAIMING LUBRICANT SAVES OIL AND MACHINE

Upkeep of bearings involves not only periodical checking up and readjustment of alinement when necessary but also of regular inspection to ascertain the condition of lubrication. Correct lubrication implies

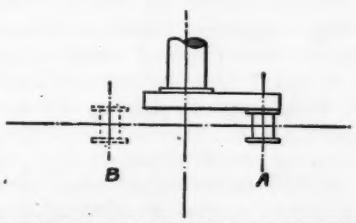


FIG. 2. CHECKING ALINEMENT OF ENGINE SHAFT

that the moving elements are separated at all points by a fluid film of lubricant, hence the lubricant must be selected for the particular use that is to be made of it and, since foreign matter carried over by the lubricant tends to break this film, it is best to keep the lubricant clean by settling, filtering or centrifuging the oil, where it is used over again as in pressure feed systems. In this way, if the oil is not adulterated in use and its viscosity reduced, there is much saving in reclaiming and reusing it. Two major conditions that tend to break down the oil film are heavy bearing pressures and high temperatures which reduce the viscosity.

Building up of the lubricant film on a rotating shaft is illustrated in Fig. 3. The factors which are essential to building up this film are: 1. Presence of a wedge-shaped clearance space free from grooving such as might

interfere with formation of an oil film. 2. Speed or relative motion of the parts by which the carrying action is accomplished. 3. Sufficient viscosity to assure that the oil will cover the surfaces. 4. Sufficient fluidity to make sure that the oil will spread well. Where oil application cannot be adapted to the conditions, the use of grease is an alternative. The lubricating essentials named also apply to sliding surfaces in which case the building up of the film is simpler.

Improper Operation Detected by Sound

It is not convenient to inspect turbine bearings but detection of maladjustment and improper operation is simple. Highly magnified sounds of operation inside of the casing are communicated readily to an observer, if he grips a pencil or, still better, a small steel rod between his teeth and, stopping up the ears with his fingers, places the point of the rod on the turbine casing. After learning the sounds accompanying proper operation, by observing these sounds when the turbine is known to be in good operating condition, it will be easy to tell in this way when operation is unsatisfactory.

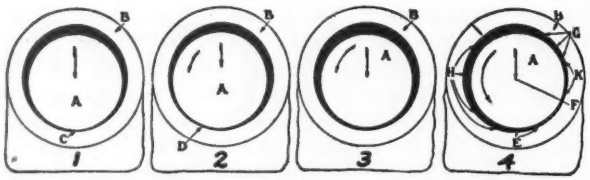


FIG. 3. MANNER IN WHICH FILM OF OIL IS BUILT UP BETWEEN JOURNAL AND BEARING. 1. BEARING WITH JOURNAL A AT REST, IN CONTACT AT C WITH BEARING B. 2. JOURNAL A WHEN STARTING, ROLLS SO THAT LINE OF CONTACT MOVES TO D. 3. JOURNAL A LIFTED BY OIL FILM AS ROTATION IS STARTED. 4. POSITION OF JOURNAL A AFTER IT HAS BEEN BROUGHT TO FULL SPEED

Proper lubrication is an important factor in successful turbine operation, therefore a thermometer should be located in the return oil lines of a flooded system close to the bearing so that the temperature can be noted regularly; a low-pressure gage should be installed in the supply line leading to bearings and relay valves so that increasing pressure, which would denote clogging of the strainer, can be noted and the strainer cleaned. The contents of the strainer should be examined carefully, as this often reveals cutting of bearings or gears.

Stoker equipment should be given regular attention because of the severe conditions under which it operates. Stoker gears should be protected from dust and should be cleaned and lubricated regularly, even where no special provision is made for lubrication.

Ring and splash systems use the same oil for indefinite lengths of time during which it is deteriorating due to inclusion of foreign matter such as carbon, steel particles, water and gasolene. Where ring oiling is employed on long bearings, it should be provided with an oil scraper and distributor. Pressure and gravity systems usually include at least an oil filter and to an increasing extent a settling tank and centrifuge. Flooded systems have the advantage that they wash away any foreign matter and carry away sensible heat. Also, due to the oil pressure, there is a greater tendency to maintain the oil film intact.

Antifriction materials, besides reducing friction have the advantage that, in extreme cases when the bearing becomes overheated due to excessive friction, the metal, which can be replaced readily, takes the punishment rather than causing the journal, which would be difficult to replace, to be destroyed.

Roller and Ball Bearings

Lubrication is as vital to a roller or ball bearing as to a plain bearing. Provision against leakage of oil and admission of dust, dirt or dampness, should be made. If this cannot be accomplished, a properly selected grease should be substituted for oil. Some roller bearings have short rollers held in a cage and supplied with inner and outer sleeves as in Fig. 4. Others consist of a set of flexible rollers made of helically wound steel as shown in Fig. 5, designed to permit a certain amount of resilience which absorbs shocks and inequalities of pressure. Still another type consists of an outer cage which entirely surrounds the inner set of long rollers, Fig. 6. Tapered rollers, Fig. 7, running in conical bearings take up end thrust, as well as carry the load on the journal. They are especially well adapted for heavy loads.

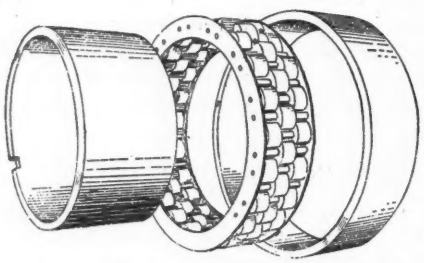


FIG. 4. ROLLER BEARING WITH SHORT ROLLERS

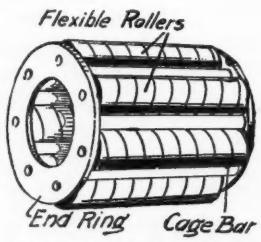


FIG. 5. ROLLER BEARING WITH FLEXIBE ROLLERS TO ABSORB SHOCK

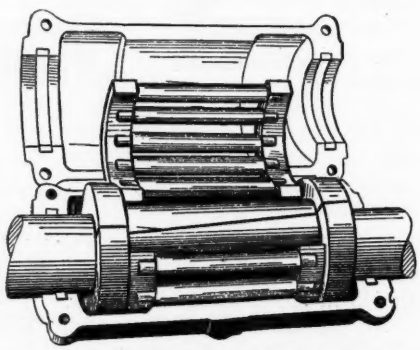


FIG. 6. ROLLER BEARING ENTIRELY ENCLOSED IN HOUSING

Due to their reduced amount of contact, ball bearings are not designed to carry as heavy loads as roller bearings. Different types of ball bearings are shown in Fig. 8.

Roller bearings usually run from 100 to 2000 r.p.m. although in special cases, these bearings have operated successfully at 10,000 r.p.m. Ball bearings speeds of over 15,000 r.p.m. are not uncommon today although for speeds in excess of 15,000 r.p.m. special methods of lubrication are necessary. Ball bearings always should be enclosed in such a manner that there will be no opportunity for dirt, grit or water to enter.

Power losses in belt drives are due to slippage and

creep, to poor belt condition and to the installation conditions. Belt slippage is a direct cause of power loss and is also a destroyer of belting. Slippage may be caused by any or all of the following: pulleys which are too small for the type and thickness of the belt employed, overloading, insufficient belt tension or slack belt, lack of belt care, formation of a hard, lumpy and glazed driving surface, atmospheric conditions, mis-

FIG. 7. TAPERED ROLLERS TAKE THRUST AS WELL AS LOAD

alinement and poor joints. The face of a pulley is always an indication of trouble from slippage. A polished surface is a sure sign of this loss of power.

Belt care should be regular and systematic, with responsibility definitely assigned. Defects should be remedied promptly, proper dressing and regular treatment being provided. If the belt becomes saturated with oil, it should be removed, cleaned and restuffed for subsequent use.

Considerable friction is caused by lack of sufficient center to center distances which necessitates high belt tension causing losses in excessive bearing friction, hot bearings and belt slip and reducing the life of the belt. A tight belt lacks elasticity, hence the load has little

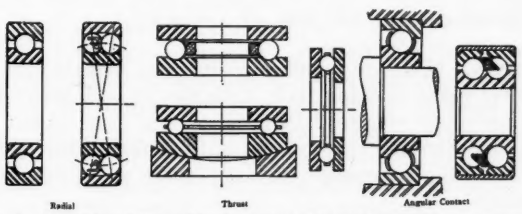


FIG. 8. DIFFERENT TYPES AND COMBINATIONS OF TYPES OF BALL BEARINGS

effect on increasing the arc of contact due to sag of the loose side. Center to center distances range from 4 ft. for transmission of 1 hp. at a 2 to 1 ratio to 32 ft. for transmission of 200 hp. at a 5 to 1 ratio. Where center distances are short, counterweighted idlers should be provided on the loose side near to the smaller pulley, or a chain drive used.

Short center drives may well be equipped with one of the excellent speed-reduction drives now on the market.

There are also available several types of multiple-belt V-belt drives especially adaptable to short center work, besides several types of special belting and pulley arrangements for such applications.

Reduction of Friction in Toothed Gearing

Friction in the use of toothed gearing has been reduced by improved manufacturing methods, use of roller and ball bearings and better lubrication. Cast teeth for gears are no longer used in modern power plant machinery; machined teeth are used whose tooth surfaces, in the case of spur teeth, have been so carefully generated that all sliding friction is avoided and pure rolling action substituted.

Proper lubrication of gear tooth surfaces is accomplished in a manner similar to that used for sliding surfaces in that the metal parts should be separated by an unbroken film of lubricant but it differs in that the contact areas of gear teeth are small, producing high pressures. Under these conditions, proper lubrication would be difficult if it were not for the fact that gear teeth are in contact only a short time, usually separating before the lubricant has been squeezed out and the film broken. It is important, therefore, to apply lubricant so that the surfaces are covered as they come in contact. As in the sliding surfaces, an oil wedge is then built up as the lubricant is pushed before the advancing contact.

Use of special alloy steels and application of subsequent heat treatment aid in maintaining the tooth surface as well as in adding strength to the teeth, thus lowering the frictional resistance.

In ordinary helical and herringbone spur gears and in bevel gears the rolling motion is accompanied by sliding motion and in worm gearing this sliding motion is continuous, hence greater care must be taken here to maintain proper lubrication. Some gear reducers, particularly those of the heavy-duty worm-gear variety are entirely enclosed and provided with a circulating oil system. Successful lubrication of enclosed gears lies in the use of lubricating oils that are adapted to the type of gear and the conditions of service. By enclosing the gears, protection is also afforded against dust and other abrasive particles. In all enclosed or bath systems, provision should be made for periodical cleaning of the parts and replenishment with fresh lubricant.

Spray Lubrication

Most high-speed turbine gears are lubricated with oil applied close to the point of mesh in such a manner that the oil is drawn between the teeth. A large quantity of oil is required, because the windage will throw a small stream away from the gears. With a flood of oil delivered in this way, the viscosity need not be as great as that required for bath lubrication.

Chain belts, in power plants are usually used in short center drives. Such belts, when constructed of links that roll on sprocket tooth surfaces, operate with little friction loss and may be run at high speed without objectionable noise.

Ontario, Can., Hydroelectric System is planning extension of its rural lines to serve farmers and loans toward the expense of installation of electrical equipment with 10 yr. to repay. Expenditure of $20,000,000 during the coming year is proposed. Work has also been inaugurated at Beauharnois on the St. Lawrence River for a 420,000-hp. plant is to be built at a cost of $65,000,000 and at Chats Falls on the Ottawa River for 250,000 hp. at expenditure of $8,000,000.

Solid carbon dioxide or dry ice, which has recently come into prominence for certain types of refrigeration, can be made from a cylinder of liquid carbon dioxide by tying a bag over the valve, tilting the cylinder and opening the valve. The liquid vaporizes rapidly and cools some of the remaining liquid below the freezing point, filling the bag with white solid carbon dioxide. This solid evaporates and will give a temperature as low as minus 175 deg. F.

Economies in the Utilization of Power

DISTRIBUTION EQUIPMENT SHOULD BE STUDIED, ALSO LOSSES IN POWER-CONSUMING APPARATUS, TO SAVE THE HIGH-VALUE ENERGY. BY EDWARD H. WALDO*

WHILE MANY businesses may turn over their capital several times a year, power plants can secure a return of only about 20 per cent on invested capital. Of this nearly one-half must go to pay interest charges and taxes, leaving only 10 per cent for operating expenses, a very narrow margin. So a small increase in operating expenditures may materially affect the ability to pay interest charges on investment.

That operating companies have met these charges in such a manner that public utility securities are among the most popular investments and that the cost of electric energy to the consumer has been continually reduced, even though during the same period the cost of fuel, materials and labor has been constantly increasing, are proof that the power industry must have been efficiently managed and increasingly so. Absence of serious labor troubles indicates that the savings have been made not at the expense of the employes but in material and managerial efficiencies.

Increasing output does not help to the same extent as in many other businesses, since extension of plant and system capacities must be purchased at approximately the same cost as first installation. The hope seems to lie in increased production and utilization economy.

BETTER AUXILIARY ECONOMY ESSENTIAL

In recent years, great advances have been made in furnace and prime-mover efficiencies, until now a kilowatt-hour is generated at the average expenditure of 1.7 lb. of coal according to the United States Geological Survey. If we are justified in assuming that the modern power plant is being built with the highest boiler and prime-mover efficiency that the present state of the art allows, then our only present outlook for saving of any moment is on increased efficiency in the use of generated energy.

In the newer installations, we note house turbines and house generators with capacities in the neighborhood of 4 per cent of that of the plant. The current statistics credit a 2½ to 3 per cent loss to electric and other departments so that only some 80 per cent of our generated energy reaches the ultimate consumer. It is evident that there is chance for improvement in this 20 per cent loss. Not all of the modern operating plants, that are careful in their heat economies, are as particular about their transmission and distribution losses. These losses consist of resistance losses in transmission line, feeder, mains and services; leakage losses, due to insufficient insulation, grounds, corona, and the like; transformer iron and copper losses; meter losses, which may be extended to include not only actual losses of the meters but also loss of income due to slow meters; stolen energy and, in the consuming equipment, idle and underloaded operation.

Of the 3 per cent station loss, aside from the necessary power for auxiliaries, which can be reduced as the efficiency of pumps and other appliances is increased, we are now using such a multiplicity of measuring and safety devices that, in the aggregate, a considerable amount of energy is used, even though each little relay or meter consumes but a small amount of power. It

*Assistant Professor of Electrical Design, University of Illinois.

must be remembered too that these consume energy 24 hr. in the day.

This kind of loss of energy is well illustrated by the common watthour meter. Though tests show residence meters with three-fourths of a watt or less consumed in the meter's potential coils, few meters in use go down to this figure. A meter with 2½-watt potential coil loss will consume over 20 kw-hr. per year, which may easily be 15 per cent of the total energy consumed and paid for by the occupant of the small bungalow in which the meter is installed. These losses could easily be halved. The annual average consumption of one of the domestic customers who constitute 20,000,000 out of the 25,000,000 customers and meter-users of the United States is less than 500 kw-hr. per year. Not less than 3 per cent of this amount is required in addition to run his meter.

While our large transformers now being built show efficiencies of 99½ per cent, leaving practically nothing which can be gained, our smaller transformers, which net a larger aggregate capacity, often have much lower efficiencies than might easily be obtained. This is suffered on the ground of the small individual loss, though like the little meter, the aggregate losses are large, much larger than those of the larger transformer, where a fraction of a per cent of efficiency gain is made a matter of careful consideration. Of course we may not expect the small transformer to have the efficiency of the larger one, both because of manufacturing difficulties and also because of the added first cost which must be paid for increased efficiency. These increased costs will mean a much greater outlay for the large number of small transformers than for the few larger ones. Still there is here a chance for saving. Particularly has it been true that many, even of the larger companies, have permitted the continuance in service of many small and therefore necessarily low efficiency transformers, where the grouping of more load on one larger transformer, possibly at expense of some large secondary wires, would in the end be a much cheaper arrangement.

Conditions cited have been largely average or above, where distribution losses are perhaps 25 per cent of the kilowatt-hours utilized. But it was not long ago when systems were analyzed in which these losses ran up to 45 per cent and doubtless some such cases still exist.

Investment vs. Operation to Increase Economy

With such figures staring us in the face for losses incurred after the electric power is generated at the plant and the necessary major losses supposedly taken care of, we may wonder how our available 50 per cent of revenue is to care for production charges and may question whether our boasts concerning our era of high efficiency engineering are altogether warranted.

We know, of course, how to decrease many of these losses but, in each case, it must be shown that it would really be financial economy to do so. The final decision must rest on the answer to the question as to whether the saving gained will pay for the extra investment or labor necessary to obtain it.

We may decrease line losses by greater investment in copper, by more expensive insulation, by locating lines where trees may be cut out, by more labor in patrol and inspection, by more efficient and expensive transformers, by more careful checking of meters. All this means greater first cost and an addition to already high interest charges, or else it means more labor charges adding to our production costs. In any case one must prove that it pays. This is not always easy to do nor is it nearly so simple as it sounds, since many factors enter into the final cost balance.

The only method by which this can be determined is by keeping careful check on all the items, the savings and the losses, which in itself entails some expense but that should easily be well repaid by added economies.

Most of our larger utilities are carefully going over old and thoughtfully planning their new distribution layouts but I think there can be no doubt that, if the same amount of skilled engineering had been put into planning the distribution that has been put into the design of the more conspicuous and imposing power plant, our average losses from generator to customer would today be much less than they are.

Energy delivered by the distributing system is also easily wasted by lack of foresight or of care in operation. Motors ill adapted to the service required, control and regulating equipment that wastes power, motors and machinery running idle, lights burned when not needed, piling up of peak load that can be avoided by a change of operating schedule, all are energy wasters. Any one loss may seem small but the aggregate may make an important item in plant expense.

Reduction of such losses is important to the consumer and of interest to the power engineer, who should be seeking to render the best possible service at a minimum of expense.

Analysis of Losses in Electric Circuits

Heating of Wiring, Operation at Efficient Loads, Power Factor Correction, Generator Losses

LOSSES IN ELECTRICAL equipment and in electric systems are usually not as subject to the control of the operator as are some of the losses in other parts of the power plant. The elimination or the reduction of losses in electrical equipment is largely a problem to be considered in the design of the apparatus for, once it is installed, there is little an operator can do toward the reduction of such losses. This, of course, is true only to a certain extent; there are ways in which an operator can display his skill and knowledge in reducing electrical losses, particularly in alternating current circuits and these will be considered here.

In the design of any electric circuit, three factors must received consideration. The conductor should be of such size that (1) it will carry the electricity to the point where it will be used without excessive drop or loss of voltage; (2) that the current will not heat it to a temperature that would spoil the insulation or cause fire; and (3) that the cost of the energy lost, that is the I^2R loss, due to the current overcoming the resistance will not be excessive.

The permissible voltage drop varies with different circuits. For a 110-v. incandescent lamp load, the conductors should be of such size that the voltage at the lamps can never vary more than 3 v. While sometimes 4 and even 5 v. variation is allowed on 110-v. lamp circuits, this is not considered good practice. Expressed in percentages, a 1 to 3 per cent drop represents good practice; a 4½ per cent drop should never be exceeded. These are percentages of the receiver or normal lamp voltage. Should these values be exceeded, the life of the lamps may be shortened or they may burn dimly when the circuits are loaded.

Influence of Socket Voltage on Lighting Costs

Low voltage at the lamp sockets due to inadequate wiring capacity is often difficult and expensive to change, particularly in old buildings. In such instances, it is often possible to select lamps with a different voltage rating from the ones in use, that is, lamps with voltage ratings more closely approaching the voltage at the sockets.

In this connection, an interesting report was made recently by T. S. Merrill of the National Lamp Works in which he points out the advantages to be gained by adapting lamps to their rated voltage. The substance of this report, which was published in the Electrical World, is included in the accompanying tabulation, which shows lighting costs as related to socket voltages. Cost of light figured for the case as follows: 200-watt lamps cost 75 cents installed in the socket. Energy cost 3 cents per kilowatt-hour. Fixed charges on interior wiring 12 per cent per year. Mechanical breakage (one lamp each 10,000 burning hours) has been included.

LIGHTING COSTS AS RELATED TO SOCKET VOLTAGES

Volts Delivered at Socket in per Cent of Labeled Voltage of Lamp	Watts Consumed by Lamp	Watts Lost in Interior Wiring	Watts at Meter	Candle-Power Produced in per Cent of Normal Candle-Power of Lamp	Cost of Lamps Consumed	Cost of Energy Consumed	Fixed Charges Interior Wiring	Total Cost of Operation	Total Cost per Candle-Power in per Cent Cost per Candle-Power at 100 per Cent Voltage
	—in per Cent of Rated Wattage of Lamp—				in per Cent of Total Operating Cost of Lighting			Installation	
80	70.9	8.9	79.8	45.4	1.1	63.1	4.6	68.8	151.2
85	77.9	6.9	84.8	56.7	1.7	67.0	5.3	74.0	130.5
90	85.0	4.7	89.7	69.5	3.0	70.9	6.4	80.3	115.6
95	92.4	2.9	95.3	83.9	5.6	75.3	8.0	88.9	106.0
100	100.0	3.0	103.0	100.0	10.4	81.4	8.2	100.0	100.0
105	107.8	3.1	110.9	117.7	19.2	87.6	8.5	115.3	98.0
110	115.8	3.2	119.0	137.2	34.9	94.0	8.7	137.6	100.2

This study shows conclusively the loss occasioned by burning lamps under voltage.

In motor circuits, the permissible voltage drop is higher than that in lighting circuits, 5 per cent being considered good practice and 10 per cent often being permitted. The question of voltage drop in conductors is closely associated with that of conductor economy. Where electrical energy is relatively expensive, the energy lost in the conductors as well as the voltage drop should be considered.

In any electrical conductor, the voltage drop is dependent upon the resistance of the conductor and the current flowing and may be expressed by the formula $e = RI$ wherein e = the voltage drop, R the resistance in ohms and I, the current in amperes. The total power flowing in an electric circuit is expressed in watts and is equal to the product of the applied voltage E and the current I, that is $P = EI$, in which P = the power in watts. That part of the total power in the circuit which is lost in overcoming the resistance and which appears as heat is expressed as the product of the current I and the IR drop or I^2R.

To decrease the power lost in an electric circuit, it is necessary to increase the size of the conductors. This, however, is usually expensive, so care must be exercised to make certain that the additional investment in copper is not so excessive as to more than counterbalance the cost of energy continuously saved. In determining the cost of power transmission, the annual charges must be considered as being made up of two components, (1) the resistance loss charges and (2) the investment charges. Resistance loss charges depend upon the resistance, the current and the unit cost of energy, and may be decreased by an increase in conductor size. This, however, calls for a greater investment with correspondingly larger investment charges.

Balance Between Cost and Resistance Losses

In order to determine the most economical conductor, Lord Kelvin in 1881 deduced a law which is to the effect that the most economical area of conductor is that for which the annual cost of energy wasted is equal to the interest on that portion of the capital outlay which can be considered proportional to the weight of copper used. On the basis of this law, it can be shown that

$$\text{cir. mils} = 55{,}867\ I \sqrt{\frac{C_e}{C_c\, A}}$$

in which, cir. mils = the area, in circular mils, of the most economical conductor. I = the mean annual current. C_e = cost of energy per kw-hr. in dollars. C_c = cost of copper, in dollars per lb. installed. A = annual charge in per cent on the cost of the conductor. This can usually be assumed to be about 10 per cent. From this equation, it will be noted that neither the voltage of the circuit nor the length are factors entering into the solution.

In Fig. 1 is shown a set of curves illustrating this law. The interest charges on the conductor increase directly with its cross section area. The resistance loss charges decrease inversely as the cross sectional area of the conductor. The total annual charge, the sum of curves representing the annual cost of conductor and energy loss, is at its minimum value directly over the point where the conductor cost and energy loss curves intersect.

Operating at Efficient Loads

In the application of electric motors in power plants and in industrial plants, it is essential that the motors selected be suited to the machines. Until quite recently, even among engineers it has been customary to apply

some form of rule of thumb when selecting motors; as a consequence today, we find many drives on which the motors are entirely too large for the work to be done. A motor too small for the work is rarely installed, since such a motor obviously will not carry the load. A motor too large for the work, on the other hand, will carry the load, but unless checked by measurement will give no indication of the fact that its efficiency is lowered. An induction motor operating at half load is less efficient as a rule than a motor operating somewhere near full load. Where a number of motors are installed, it may be well to check over carefully the power requirements of each machine by measuring the input and comparing that with the rating on the motor nameplate. If there is a considerable difference, the motor

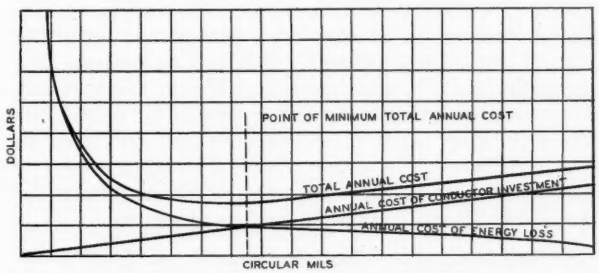


FIG. 1. CURVES ILLUSTRATING KELVINS LAW FOR DETERMINING ECONOMICAL CONDUCTOR

can, no doubt, be replaced with a smaller one to advantage.

In general, the advantages accruing from the use of smaller motors are as follows:

(a) Improved power factor.
(b) Higher efficiency.
(c) Reduced energy consumption.
(d) Elimination of expensive compensators.

Reducing Loss Due to Low Power Factor

Among the items enumerated above, is that of power factor. Power factor is an important item in the operation of an a.c. electrical system and is often a fertile field for cutting losses. Low power factor results in increased losses in generators, exciters, distribution lines, transformers and in the consumers' plant. In a system working at 70 per cent power factor, the losses will be twice as great as they will if working at unity power factor. This increased loss is caused by increased currents for the same amount of power, and stronger fields are needed by the generators to furnish this power which causes undue heating. It follows from this, that, if the losses are to be kept the same at 70 per cent power factor as they are at unity power factor, the cross section of the copper will have to be doubled.

In the following table are shown the currents at various power factors that will be required to carry a 75-kw., 550-v., single-phase motor load:

Per cent power factor	100	90	80	70	60	50
Current	136.3	151.5	170.5	195	228	273
Kv-a.	75	83	94	107	125	150

Another fact which this table shows well, is that at lower power factors there is considerable line drop, which necessitates impressing over-voltage at the supply end, making the voltage regulation poor. The regulation of transformers is approximately one per cent at unity power factor, and three per cent at 70 per cent power factor.

Power factor is the ratio of the power current to the total current flowing in the circuit. When the voltage and current become out of phase, the current may be considered as being made up of two currents, one in phase with the voltage and the other 90 deg. out of phase with it. The out of phase current is called the reactive or wattless component. It is stored energy that is being transferred back and forth through the circuit

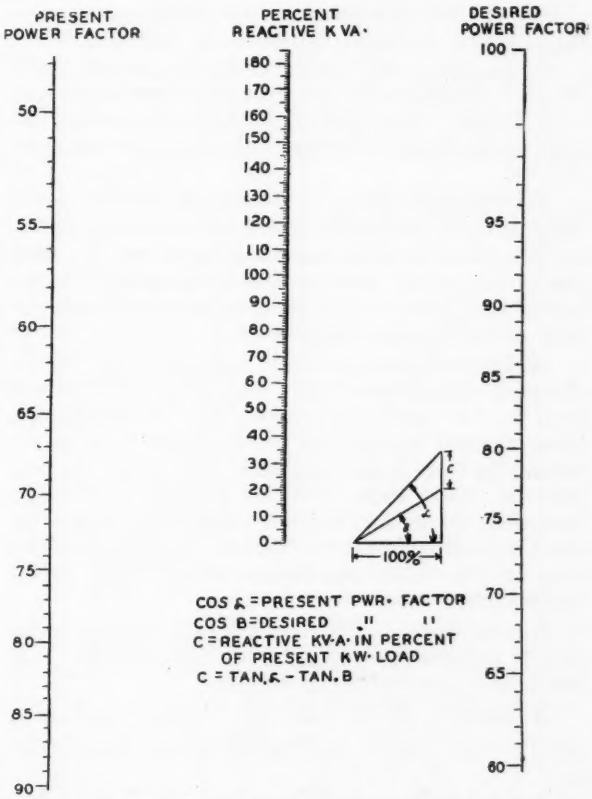


FIG. 2. CHART FOR USE IN DETERMINING REACTIVE KV-A.

with no resulting losses, except the heat losses due to resistance.

Lower power factor may be corrected by installing either synchronous or static condensers. In the last few years, the static condenser has gained greatly in popularity and where only a small amount of corrective effect is necessary, it is ideally suited.

A condenser, static or otherwise, is a device in which electrostatic energy may be stored. Both the electrostatic and magnetic fields which surround electrical conductors require energy. When a magnetic field is established, energy is required. The current representing this energy travels over the line.

Electrostatic fields are set up when insulation is subjected to a potential stress. This energy is returned to the line, the same as the energy from the electromagnetic fields at every half cycle but it is 180 deg. out of phase with the electromagnetic energy. The static condenser, therefore, acts as a storage tank receiving the electromagnetic energy as it is returned to the line and supplying it back to the motor as needed, thus con-

fining the wattless current to the portion of the line between the condenser and the load, and avoiding its transmission over the line.

The power factor of the line between the condenser and the load and the power factor of the load remain unchanged. None of the operating conditions of the motor are changed other than a possible improvement in performance, due to better voltage regulation being maintained at the terminals of the motor.

Determining Corrective Kv-a.

In order to determine the corrective kv-a. required to correct the power factor in any particular instance, the following procedure will be found convenient.

Divide the present kw. load by the present power factor to determine the kv-a. under present conditions.

Determine the reactive component by taking the square root of the difference of the squares of the kv-a. and kw.

Determine the kv-a. at the new or desired power factor by dividing the kw. by the per cent power factor.

Determine reactive component as above, but with new power factor. Subtract reactive component in the second case from that of the first case and obtain the kv-a. of the condenser required.

In Fig. 2 is shown a chart constructed by the engineering department of the Westinghouse Electric and Mfg. Co. for quickly determining the per cent reactive kv-a. required to raise the power factor to a desired value. To find the per cent reactive kv-a. necessary to raise the power factor from the present power factor to desired power factor, lay a straightedge across the chart connecting these two values. Read the reactive kv-a. in per cent of the present kilowatt load on the center scale.

In some instances, the loss due to low power factor may be reduced by rearranging the motors so that they will operate more nearly at full load.

Reclamation of the heat losses in the windings of electric generators is a comparatively recent practice. Until the advent of large turbine generators, the heat loss from generators was not excessive and the normal surface of the machines was such that this heat was easily radiated. As machines increased in capacity, at the same time undergoing a reduction in volume per kw. output, the surfaces of the machine could no longer radiate the heat produced in the windings, so forced ventilation was adapted. The use of forced ventilation made it possible to reclaim some of this heat, either by using the warm air from the generator as combustion air in the furnaces or by cooling this air by means of condensate.

While several plants were built using the generator air as combustion air, the general adoption of the air preheater offset the advantages to be derived from this practice and today it is not used to any considerable extent. Similarly, with the condensate cooling system, the increasing use of extraction heaters has made the use of condensate generator air cooling systems less attractive than it was formerly. Today, the tendency is to use circulating water for generator air cooling, no attempt being made to reclaim the heat produced in the generators. In small plants, however, where no extraction heaters are used, the use of condensate for generator air cooling can be used to advantage.

Shutting Down Idle Machinery and Lights

Proper attention to the shutting down of idle equipment and the turning out of electric lights not in use, will often result in a considerable saving. This, of course, is extremely obvious but what is not so obvious is that this can be brought about by a convenient arrangement of switches and control equipment. If the control switch of a machine is located conveniently with respect to that machine, an operator is more likely to stop the machine during time intervals when the machine is not in use than he would be if the switch is placed in an out of the way location. The same, of course, is true of lamps and lighting circuits—switches must be arranged so that their manipulation can be effected without undue effort.

Saving Energy in Compressed Air Systems

Efficient, Well Maintained Machines with Good Lubrication and Tight Piping Systems Reduce Losses

ENERGY INPUT into compressed air systems is usually through the compressor by means of an engine or electric motor, although reheating the air just before it is used in compressed air tools is sometimes practiced either to increase the volume, to obtain additional work, or for the purpose of preventing moisture condensation.

As with combustion process, these are losses which, although they cannot be eliminated, should be reduced to the minimum. Energy losses due to inefficient prime movers or faulty transmission losses such as poor chains or belts are not considered part of the compressed air system, as they have been treated in previous articles.

Friction Losses

Friction losses form an important part of compressor losses; friction of pistons, stuffing-boxes, crossheads, pins and journals, combine to take a toll which even in a first-class machine may run up a considerable percentage of full load input. For instance, a certain 2300-c.f.m. compressor required a full load brake horsepower input of 351 hp. of which 38.5 hp. represented the no load horsepower, made up largely of friction but including some cylinder losses as well.

This loss is a function of machine design and maintenance. Some of the energy is dissipated to the air through radiation while some is absorbed by the oil. Except in large size machines, compressor lubrication is by the splash system and the oil is cooled entirely by radiation. Some of the very large machines have oil coolers but these are not common. Keeping the bearing surfaces in good condition and using the proper oil are about all the engineer can do to keep these losses at a minimum. Cylinder losses due to leakage and valve resistance should also be included in this group.

The second great loss comes about through the increase in temperature due to compression itself. The

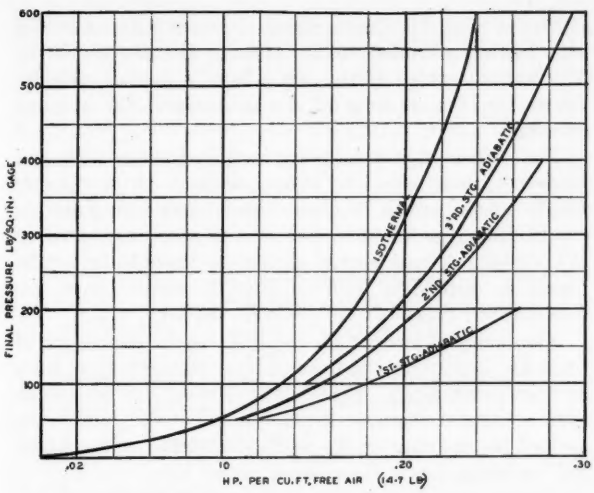


FIG. 1. CURVES SHOWING THE ENERGY REQUIRED TO COMPRESS 1 C.F.M. OF AIR BY ISOTHERMAL AND ADIABATIC COMPRESSION

process of increasing the air pressure takes a certain amount of work. The most efficient compression is isothermal compression where the temperature of the air is maintained constant during the process. Heat cannot be carried away fast enough and compressors tend to follow adiabatic compression, that is compression without the addition or subtraction of heat.

In order to reduce the power necessary for compression, the air during compression is cooled by cylinder water jackets and intercoolers. The more nearly the actual compression line approaches the isothermal lines the more efficient the cooling system.

Theoretical horsepower required to compress 1 c.f.m. of free air isothermally and adiabatically is shown in Fig. 1. Isothermal compression is independent of the number of stages, but adiabatic compression is not because between the stages the air is cooled back to the initial temperature, giving an actual compression curve somewhere between isothermal and adiabatic, the exact location depending upon the efficiency of the cooling system.

Additional power indicated between any of these curves and the isothermal curve goes into sensible heat and increases the temperature of the air. This temperature increases as shown in Fig. 2 for various conditions, n being the ratio of specific heat at constant pressure to the specific heat at constant volume. It is the exponent in the well known equation:

$$PV^n = \text{Constant}$$

Where P = pressure in pounds per sq. ft.
V = volume in cu. ft.
n = $C_p \div C_v$ = (spec. heat at const. press. over spec. heat at const. vol.)

The more efficient the jacket cooling system is the lower the value of n. Knowing the final temperature of the compressed air for adiabatic compression, the heat above the initial temperature of 60 deg. F. can be calculated from the specific heat of air at constant pressure, about 0.243 B.t.u. per lb. Using 13.35 cu. ft. of free air per pound would give a value of 0.018 B.t.u. per cu. ft. of free air.

With the compression range equally divided between the different stages and with an aftercooler, the total amount of heat is about equally divided. For instance, with two-stage compression, about half the heat or about 0.009 B.t.u. per cu. ft. of free air would be removed in the intercooler and about the same amount in the aftercooler, if an after were used. If not, this heat energy would be dissipated in the air by radiation. The specific heat values given refer to 1/13.35 lb. of air, that is one cubic foot of free air; after compression the volume will, of course, be much smaller but the weight will be the same.

Heat Loss in Jacket Water

In a 500-cu. ft. two-stage compressor, taking 148.6 i.hp. and compressing to 300 lb. per sq. in. gage. The first-stage water gasket carried away 678 B.t.u. per min. the second-stage jacket water 948 B.t.u. per min. and the intercooler 2070 B.t.u. per min., an appreciable part of the input to the motor.

In this particular case, no aftercooler was used, the intercooler water being divided between the two cylinders. Water entered the intercooler at 58 deg. F. and left at 91 deg. after which it went through the jackets leaving the high-pressure cylinder at 111 deg. F. and the low-pressure cylinder at 132 deg. F. The total amount circulated was 62.5 lb. per minute or about 7.5 g.p.m. which is about half the amount recommended by the compressed air society.

Usually cool water is used on both the aftercooler and jacket and no attempt made to utilize the heat in the water. This can be, and is being, done, however, and is particularly desirable where aftercoolers are necessary in order to dry the air for process work. Warm water from the coolers can be used direct where needed or the water can be run first through the coolers and then on to the regular steam heaters. Heat picked up in the coolers causes a reduction in the amount of heat absorbed from the steam. Coolers of this type must, however, be designed for the necessary water pressure.

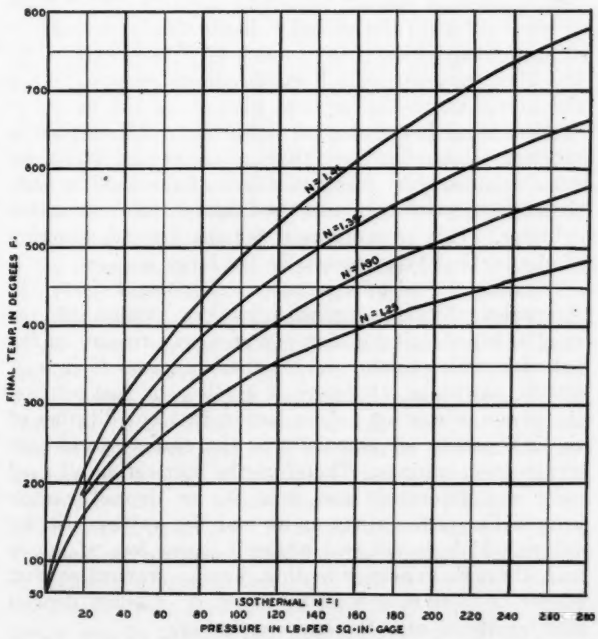


FIG. 2. TEMPERATURE OF AIR AT END OF COMPRESSION

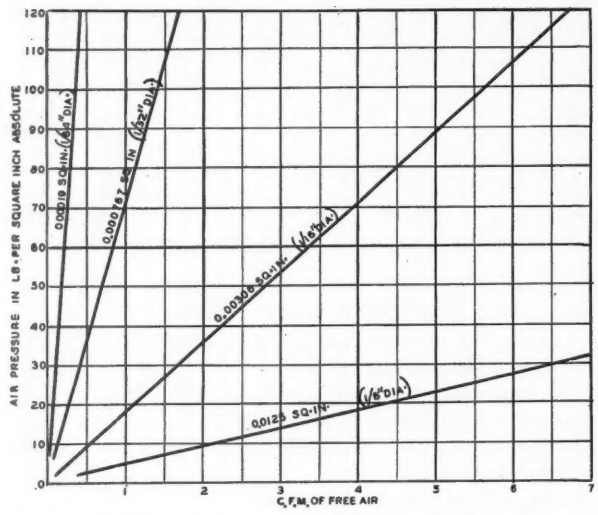

AIR PRESSURE IN LB. PER SQUARE INCH ABSOLUTE
C.F.M. OF FREE AIR
0.00019 SQ.IN. (1/64" DIA.)
0.000187 SQ.IN. (1/32" DIA.)
0.00306 SQ.IN. (1/16" DIA.)
0.0125 SQ.IN. (1/8" DIA.)

FIG. 3. LOSSES IN CUBIC FEET OF FREE AIR PER MINUTE THROUGH ROUND HOLES

Piping leaks are a third and the most serious sources of loss. They are the most serious because they are preventable whereas the other two are not. It is surprising how losses through small holes mount up.

These losses in cubic feet of free air per minute are shown by Fig. 3. These curves are drawn for a round hole having rounded inner edges. The shape of the hole and character of the edges have a considerable influence on the amount of air discharged for a given pressure.

An orifice in a thin plate would discharge around 64 per cent as much as shown while a short tube or nipple whose length is about three times the diameter would discharge about 80 per cent as much as shown on the curves. Actual energy wasted by these leaks can be found by referring back to Fig. 1, which shows the power input necessary to compress the air.

Obviously curves of the type shown in Fig. 3 are of little use in finding the losses except through such holes as open drain pipes. Leaks due to cracks are impossible even to estimate because it is impossible to determine the area of the opening or the coefficient of the orifice which will be much lower than for a round hole.

These curves do, however, show that the importance of losses is proportional to the pressure and to the size of the opening. A hole in a 100-lb. receiver only 1/32 in. in diameter would waste about 1.5 c.f.m. of air equal to, with adiabatic compression from Fig. 1, about 0.18 hp. This does not include the friction losses of the compressor or prime mover, which would bring the loss up to around 0.25 hp. with a plant thermal efficiency of 10 per cent or over 6000 B.t.u. per hour.

Heat Unit Salvaging in a Diesel Engine System

ANALYSIS OF HEAT LOSSES IN JACKET WATER AND EXHAUST GASES AND OF METHODS USED TO RECLAIM MUCH OF THIS HEAT

CONSIDERING the internal-combustion engine as a machine, the problem of reduction of friction is the same as in any other high class machine. Since it functions also as a combustion apparatus, however, other considerations are involved. In the first place, few lubricating oils can withstand the high temperature of combustion in the cylinder, hence this oil should be of such composition that so much of it as is exposed to this high temperature is burned without residue. Since the lubricant on the exposed portion of the piston is burned at each impulse of the engine, the surface is lubricated less effectively than where the oil is spread more completely by many traverses of the moving part, therefore, greater care must be taken in lubricating the cylinder. This is one reason for the general adoption of the vertical type, especially for large engines.

Sealing the pistons is another important factor in internal-combustion engine operation because of the need of maintaining a high compression pressure in the cylinder, which in the case of Diesel engines is at least 500 lb. per sq. in. Leakage of gasolene or fuel oil past the piston causes not only a loss in fuel but dilution of the lubricating oil, especially in the case of crank-case compression engines. Therefore the lubricating oil used must not decompose and gum up or deposit carbon around the piston rings or around the valves. Sticky valves, which do not seat properly, cause loss of power and, through improper cooling, become warped so that sooner or later they must be replaced. Carbon deposit also interferes with the ignition timing.

Methods of lubrication employed on various parts of combustion engines are drip-cup, splash and forced-feed. Following the general refinement of operation which has been developed during recent years in Diesel practice, there is a greater tendency toward forced or gravity-feed lubrication for all bearings and removal of all impurities from the lubricant by filters in all pipe lines and finally by periodic or continuous reclamation. Lubricant cooling is now a common procedure in modern Diesel plants.

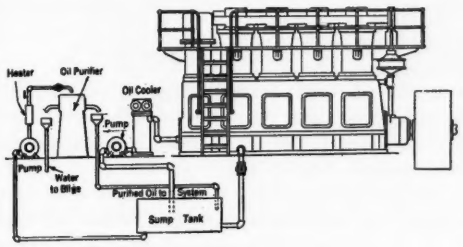
HEAT LOSSES IN COMBUSTION ENGINES

High temperatures which occur in the combustion chamber and cylinder of an internal-combustion engine make heat losses inevitable. In all engines heat is generated, some of it is transformed into work or lost by heat transfer and the balance rejected in the exhaust. Heat thus rejected is unavailable for doing work, as far as the engine from which it was rejected is concerned but heat that is lost from the time of ignition until the exhaust valve opens is partly available, depending upon the position of the piston when the loss occurs. Heat removed from the engine cylinder by the cooling fluid and by radiation, which is from 30 to 35 per cent, may be divided into losses during the following periods; combustion, expansion and exhaust.

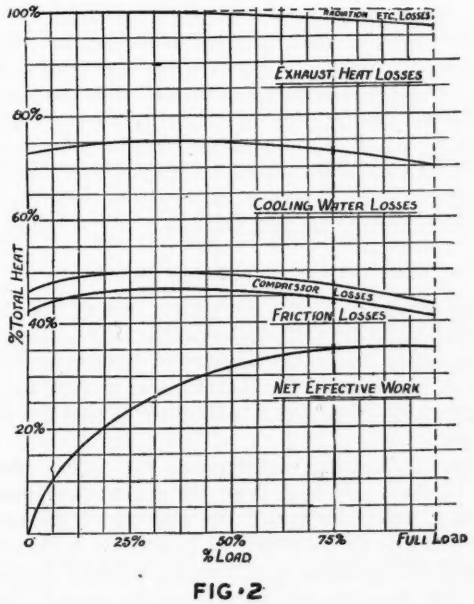
During the combustion period, the temperature difference is high. The heat transfer coefficient is high due to great turbulence, small exposed surface and short time of combustion, so that approximately 7 per cent of the total heat is lost during this period. Of this the amount available depends on the compression ratio

used, being for a 5 to 1 compression ratio 35.9 per cent.

During the expansion stroke, the temperature is falling rapidly and the heat lost during this period will be about 8 per cent. Availability of this energy varies from 35.9 per cent, at the beginning of the stroke to zero at the end, giving an average of 17.9 per cent. The balance of the heat loss, which is comparatively high, occurs during the exhaust stroke. High velocity of exhaust gases through the exhaust port and connections results in high heat transfer at these places. The average loss during this period is about 17 per cent principal. The factors affecting the heat loss to the engine walls may be enumerated as follows: time of ignition of charge, time of combustion of charge, speed, load, shape of combustion chamber and size of cylinders. While these heat losses are inherent to the engine cycle, material reduction of most of them is now possible when the plant is considered as a whole.



FIG·1



FIG·2

FIG. 1. FORCE-FEED LUBRICATING SYSTEM WITH OIL PURIFIER AND COOLER

FIG. 2. OIL-ENGINE HEAT BALANCE SHOWING ABOUT 50 PER CENT OF THE TOTAL HEAT IN JACKET-WATER AND EXHAUST-GAS LOSSES

Thermal efficiency of Diesel engines always has been high. Improvement in economy of operation has been due to Diesel plant refinement, to improved adaptation of the Diesel engine to specific loads and more recently to waste heat recovery.

Besides the addition of the lubrication accessories already mentioned, the principal plant refinements which have led to heat savings have been, cooling water treatment which improves the water circulation, hence heat transfer; fuel-oil purification which improves the combustion process; equipment with temperature and pressure instruments which enable better control and more efficient operation and lastly the keeping of records which lead to better performance. Between ¾ and full load there is practically no difference in the rate of fuel consumption in Diesel engines. The difference is small even to one-half load, below which a Diesel engine should not be operated, load distribution among units being regulated to control this.

Diesel Graduates from Standby Field

As standby and peak-load units, Diesel engines have long saved heat units that would otherwise have been wasted by steam standby units. Recently, by the study of the heat balance of certain plants it has been discovered that best economy of operation is obtained in certain cases, if the Diesel is operated at full power at all times and steam units, formerly used as primary motive power, relegated to standby and peak-load service. One such plant is at the Easthampton Electric Light & Power Company's plant.

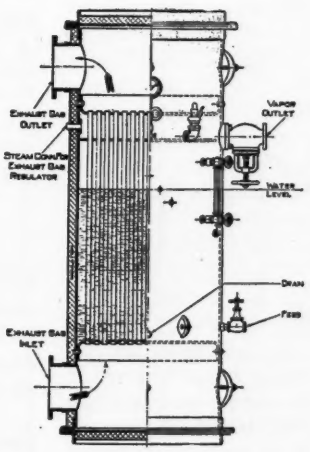


FIG. 3. GAS-TUBE TYPE OF HEAT ECONOMIZER WHICH MAY BE USED TO RAISE STEAM TO 50 LB. PRESS.

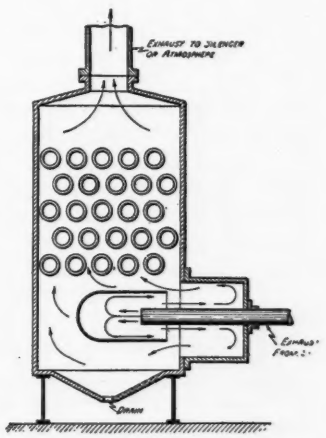


FIG. 4. WATER-TUBE TYPE OF HEAT ECONOMIZER SHOWING ACTION OF DEFLECTOR IN EQUALIZING AND DISTRIBUTING THE HEAT

A more recent installation of this kind is that of the Hotel New Yorker where the important reason for installing a Diesel engine was its ability to improve the balance between the electrical power load and the heating load. Because of its high thermal efficiency and the employment of waste heat recovery, the Diesel engine installed in the New Yorker will be able to carry the summer electrical load with a minimum of heat wasting, amounting to only a fraction of the heat which would be rejected by the steam engines in the plant at times when only a small amount of exhaust steam is required for heating purposes. During the summer months, it is planned to operate the Diesel at full load and reduce the steam power load to such an extent that no exhaust steam will be thrown into the atmosphere. Heat from jacket water will be used for boiler feed heating, while

water heated by the exhaust gases of the engine will be used for lavatory, laundry and kitchen.

Waste Heat Recovery

Two sources of heat recovery are available in a Diesel installation, the jacket water and the exhaust gases.

Inspection of an oil-engine heat balance as illustrated in Fig. 2 reveals the fact that about 50 per cent of the total heat is represented in jacket water and exhaust gas losses, most of which are recoverable. Waste-heat has been recovered from Diesel engines successfully for a number of years but only recently has its general adoption been seriously considered. At the plant of the American Chocolate Almond Co. in Jersey City, N. J., the reclaimed heat is used to preheat the feedwater of the heating boiler. The city of Rensselaer, Ind. is using a waste heat economizer in connection with a 500-hp. Diesel engine, the heat so re-

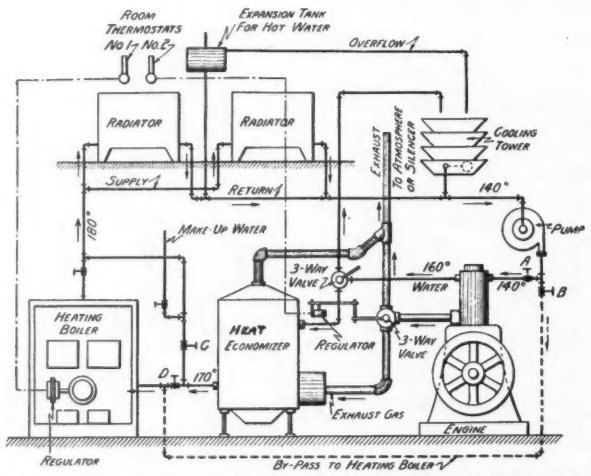


FIG. 5. TYPICAL LAYOUT OF EQUIPMENT FOR UTILIZING WASTE HEAT FROM A DIESEL ENGINE

claimed preheating boiler feedwater in connection with a central heating plant for three large school buildings.

Whereas no special apparatus is necessary for the recovery of heat from the jacket water, so that there is no loss in this recovery, salvaging heat from the exhaust gases requires the installation of some form of heat economizer because the exhaust gases contain noxious elements such as sulphur dioxide, carbon monoxide and unsaturated hydro-carbons, hence cannot be permitted to mix with the water which is to be heated.

Temperature differences between the combustion gases and the water in a coal burning boiler vary between 750 and 2800 deg. F. In order to extract the heat from the exhaust gases of a combustion engine, in which this temperature difference is much less, it is necessary to use a greater amount of heating surface. While approximately 33,500 B.t.u. may be transferred per square foot of heating surface per hour in a steam boiler, only about 600 B.t.u. will be transferred in the case of a heat economizer for oil engine exhaust, as the temperature of exhaust gases discharged from a 4-cycle oil engine running at full load rarely exceeds 800 deg. Heat loss in the exhaust pipe can be prevented by proper lagging or heat can be abstracted at this point by water jacketing the pipe.

Fuel consumption of a Diesel engine is directly proportional to the load, except for lower efficiency at less than half-load operation and, since the possible heat recovery is in direct proportion to the amount of fuel burned, the amount of heat available for heating is readily found. It must be remembered, however, that at light loads there is a correspondingly less amount of heat available, therefore, in ascertaining whether or not the installation of a heat economizer is advisable, the plant load curve over a sufficient period must be considered.

Types of Heat Economizers

Two types of heat economizers, corresponding to fire-tube and water-tube types of ordinary steam boilers are shown in Figs. 4 and 5. A heat economizer should be so constructed that a high velocity of the exhaust gases is obtained in order to have high efficiency of heat transfer, as this rate increases with increase in velocity of the gases. In some of the older types of heat economizers, over 2 sq. ft. of heating surface was allowed per engine horsepower. Half of this amount is now considered ample for ordinary purposes.

Steel plate is used in the construction of the economizer illustrated in Fig. 3 while cast iron is used in Fig. 4, the latter being equipped with mechanical soot blowers for keeping the heating surfaces clean. Frequently, where the engine load varies considerably, it may be advisable to include a supplementary oil-fired boiler in the heating system in order to make up for deficiencies during very cool weather.

Regulation of Heating System

Employment of a heat economizer, use of heat from the jacket water of a Diesel engine and provision of a supplementary boiler are illustrated diagrammatically in Fig. 5. Ordinarily the jacket water system and the economizer or exhaust-gas heater are placed in series as shown.

When the heating requirements are within the capacity of the waste heat from the engine, temperature regulation would be under the control of thermostat No. 2, which is so connected as to operate a three-way damper in the exhaust pipe, turning varying quantities of hot gas into the economizer and bypassing the remainder to exhaust.

When the outside temperature is such that the heat available from the working range of the jacket water is sufficient or in excess of that needed to warm the building, the economizer will be entirely shut off, temperature regulation being secured by passing part of the jacket water through the radiators and sending the rest to the cooling tower. A 3-way valve in the jacket discharge pipe beyond the engine, may be used for this purpose.

In the above consideration, heat recovery from exhaust gases has been considered only from a 4-cycle engine, as scavenging air mixes with the exhaust gases of a 2-cycle engine in sufficient amount to cool them considerably and make heat recovery from this source uneconomical. Waste heat recovery should, however, be fully investigated and heat requirements, as well as heat available under the various conditions of operation, be carefully checked for no longer can we disregard the question of waste-heat recovery in the design of a Diesel power plant.

Power Demand vs. Brick Machine Operating Conditions

MUCH IS to be learned by industrial power plant engineers about the power consumption of the various machines for which they supply power in the form of either steam or electricity. Because of the relative cheapness and simplicity of electric meters and the fact that the management is usually responsive to requests for such instruments it is usually easy to obtain data on motor-driven machines.

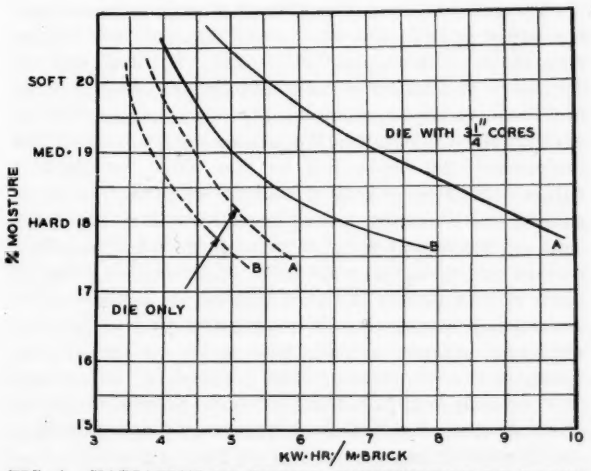


FIG. 1. VARIATION OF POWER CONSUMPTION BY BRICK MACHINE DUE TO MOISTURE CONTENT IN CLAY AND TO EFFECT OF USE OF CORES

Knowledge of power consumed by different units is of value to the power plant man in a number of ways: First, it helps him to determine the effect of varying conditions upon his load; second, it enables him to plan the most economical use of machines, if more than one or two are available as in a large plant; third, such knowledge is of vital interest to the production department which must, as a rule, depend upon the power engineer for such information and, if used tactfully, it can be of advantage to the engineer in promoting cordial relations between the various production departments and the power department so that the plant load factor may be improved by timing the operation of different machines to run non-simultaneously. This is the big advantage and, although it is important to all power plants, it is more readily converted into dollars and cents in plants that buy all or some of their power and where cutting the peak means a considerable saving in the monthly power bill.

Brick machines as a rule are operated without much knowledge of the effect of different variables on power consumption. For this reason, the curves shown are of particular interest, since they show the effect as an example, of moisture content of material on both the capacity and power consumption of the machine using two different kinds of dies, both with and without three 1¼-in. diameter cores. The first die used, designated as A on the curves, consists of two solid castings which fit together to form a tapering funnel terminating in a standard 4 by 8½-in. opening. About a quarter of the way to the orifice is a lubricating groove through which oil under pressure can be introduced.

The second die, designated as B, is made up of a number of rectangular shaped castings whose inside surface is formed also in funnel shape and terminates in the same sized orifice. Lubrication is provided along the last half of the die. Results of careful tests, as reported by D. P. Ogden before the American Ceramic Society, are shown in Figs. 1 and 2 which were plotted from tabulated data.

Figure 1 shows the variation of power consumption with moisture content and also the effect of the cores in both types of dies. In all cases, a decided increase in power consumption with a decrease in the moisture content is shown, although this change is much more

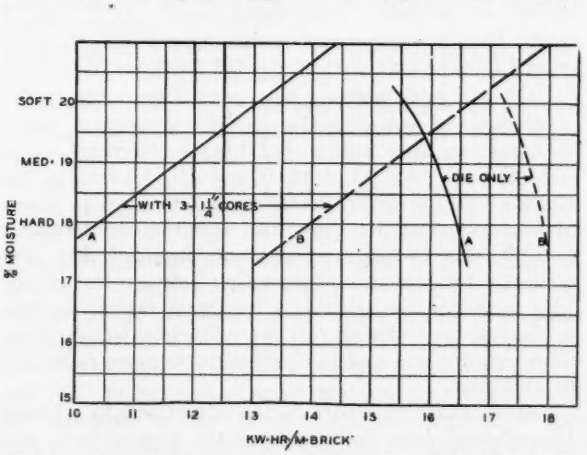


FIG. 2. EFFECT OF MOISTURE IN CLAY ON CAPACITY OF BRICK MAKING MACHINE

marked when cores are used. Thus in the case of die A alone, increasing the moisture content from 18 to 20 per cent reduced the power consumption from 5.3 kw hr. to 3.7 kw-hr. This same moisture change with dies reduced the power consumption from 9.3 to 5.5 kw. hr. or roughly 60 per cent as compared to 70 per cent in the first case.

Corresponding figures with die B are 4.6 to 3.55 kw-hr. for the die alone and 6.7 to 4.2 kw-hr. with cores, which resulted in power decreases of 77 and 63 per cent respectively, agreeing on a proportional percentage basis very well with the results for die A. Relative power consumption of the two dies is affected little by the moisture content of the column. Die A uses about 15 per cent more power than B alone and about 30 per cent more power with cores.

Effect of moisture on the capacity is shown very strikingly in Fig. 2. With the die alone, changes in the moisture content have relatively little effect on the capacity, although there is a slight tendency to slow up the machine as the column softens. Exactly the opposite effect is found with the cores in place, in which case the capacity is materially affected by the moisture content. In fact, a decrease from 20 to 18 per cent reduces the capacity from 13.1 M. to 10.4 M. or to about 80 per cent with die A and from 17 to 13.9 M. or to about 80 per cent for die B. Under any practical operating condition, cores reduce the capacity when using die A although with die B the capacity, with moisture content of about 20 per cent, is apparently unchanged but the power consumption from Fig. 1 is increased about 50 per cent.

During the tests, the auger machine was run continuously and a constant quantity of shale was fed to the pug mill. When the auger machine failed to take the output of the pug mill, the disk feeder was shut down.

A study of these curves will show an engineer why the motor sometimes pulls 45 and sometimes 90 kw. under apparently the same working conditions and with the same number of cuts per minute.

Brooklyn, N. Y. PAUL F. ROGERS.

Practical Knowledge for the Asking

AMONG OTHER interesting articles in the November 15 issue, I have read the editorial Off Duty, which strikes me as being particularly good. If I may, I would like to make a few comments particularly with regard to the latter part of the Off Duty on page 1237.

"If you have nothing else, read Power Plant Engineering. If you find that it fails to interest you—well, you can always go to bed" is the statement which ends the article. As most, if not all, readers of the paper are in some way related to or interested in power plant engineering, it seems to me that reading the paper could hardly fail to interest them, provided they seek earnestly for something interesting between the covers. This includes the valuable advertising matter as well as the regular technical articles, editorials, letters, questions and answers and the various news notes contained in each issue.

As an example, I turn to the advertisement on page 12 and read near the middle of the page, "It is estimated that for every 10 deg. rise in feedwater temperature, there is a saving in fuel bills of one per cent. Thus condensate at 280 deg., cooled to 180 deg., represents a reduction in fuel bills of approximately 10 per cent." Then further on, "A 40-page manual on the subject is offered free to any who wishes to send for it."

Are there not many power engineers who would benefit in learning something further about the saving in heating feedwater, than that contained in the one statement in the advertisement? The 40-page pamphlet is worth sending for.

Again; the advertisement on page 122, relative to heat insulation: "1015 deg. F. inside, 140 deg. F. outside." Without the 7-in. thickness of insulating material referred to, how much heat would have been lost in radiation? How many engineers know? Yet how easy it would be to learn from the advertiser, how to solve the problem! It is all for the asking.

One more example: I refer to page 128, advertising relative to "copper-steel pipe." I wonder how many power plant men know about copper-steel pipe. Why is it used? This can all be learned from a bulletin published by the company which is offered gratis to any who write for it.

There are many more offers of a similar character—the paper is full of them. Advertisements are indicative of educational material back of them and all engineers should have such material at hand. Textbooks on abstract principles are good; we cannot do without them; but after the principles are learned and understood the books can be laid aside for possible future reference. Catalogs and various other forms of advertising literature in engineering relate to the practical application of abstract principles and these applications are changing with trial, so, from this point of view, after a person has once learned his fundamentals, advertising literature is of more value to him than his textbooks, strange as this may seem. After all, the practical use of what we have learned is what counts and we can get this through such papers as Power Plant Engineering and from the many helps offered in its advertising pages.

So again, referring to the editorial Off Duty, I would suggest that whether or not you have anything else to read, read Power Plant Engineering and, having found something interesting, take advantage of it; and then—"go to bed."

Brooklyn, N. Y. CHARLES J. MASON.

Asphyxiated Fires

EVERY YEAR, with the appearance of cold weather come complaints that "the coal won't burn," "the stack won't draw," and similar complaints. The coal and the size of coal, in fact, everything including the stack, had functioned without trouble up until the appearance of very cold weather. Then the trouble started. The remedy is simple and the cause readily understood. At the same time, the condition may be readily overlooked, so causing considerable trouble due to loss of steam pressure.

What happens when the weather gets very cold? Unless proper provision has already been made for the comfort of the men, the first thing that happens when cold weather comes is to shut the doors and windows

and plug up the various cracks and openings. By doing this, the air supply to the fires is cut off. Insufficient air reaches the fires; they are asphyxiated and the combustion rate is curtailed accordingly. Hence, "the stack won't pull." The undersigned knows of a number of small plants with several boilers are installed where considerable effort is required to open the boiler-room door during cold weather on account of the partial vacuum in the boiler room. A draft gage connected up during such times will show a draft as high as 0.16 in. This is about as much draft as is ordinarily found at the base of a stack, which leaves practically nothing to draw the air through the fuel bed. The draft gage should be connected up to the boiler room from the outside, a rubber tube being inserted through the keyhole in the door. Open the doors or windows so that sufficient air may enter and there will be no more trouble.

Incidentally, the piping system for steam and for hot and cold water and fuel oil are always planned and carried out carefully. Yet, practically no provision is made in the ordinary power plant for the supply of air to the fuel bed. Why is this, when a greater tonnage of air is handled than of water or coal? While a pound of coal requires, theoretically, about 12 lb. of air for combustion, anywhere from 16 to 40 lb. of air are usually used. The evaporation per pound of coal will range from 5 to 10 lb., so that the weight of air handled is twice to five times as great as the amount of water. It would seem, therefore, that better provision should be made for the admission and handling of the air to the fuel bed.

Meanwhile it should be borne in mind that fires cannot burn when they are boxed up and that closing windows and doors, where no definite provision has been made for incoming air, results in choking the fires at a time when air is needed most. Incidentally, stack draft increases materially as the temperature at the top of the stack decreases. In other words, the colder the weather or lower the outdoor temperature, the greater the draft created by the stack for a given furnace temperature. For this reason, fires should burn better during cold weather and they will, if the air supply is not cut off at the ashpit or at the boiler room. These facts are so obvious that it might seem unnecessary to mention them. Yet, considerable trouble is experienced every year from this simple cause, which in some cases results in changing coal sizes, in disorganized production, due to lower steam pressure and considerable other expense and annoyance.

Do not box up your fires and remember that your furnaces and stack are handling a greater tonnage of air than of any other raw substance.

Chicago, Ill. C. G. Crowley.

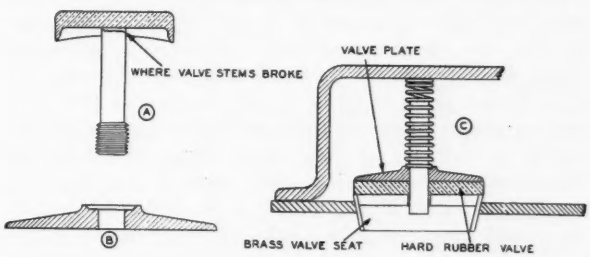
Construction Change Avoids Valve Breakage

Breaking of heads from valve stems caused us considerable trouble in connection with exhaust valves of our 8 by 8 by 12 in., simplex, vacuum pump used on the return lines of our heating system. This pump has two suction and two discharge valves, each 5 in. diam., ¾ in. thick, and provided with ⅞-in. holes for the valve stem. On top of each valve, which was shaped as shown at A in the illustration, was a plate B, 4½ in. diam. and provided with a recess in which the valve spring was inserted.

Every time a valve head broke off, the head, spring and valve plate would slip off the stem and the head and spring usually were passed out through the discharge line while the valve plate played tag inside of the deck, usually spoiling at least one and sometimes both valve seats.

After trying in vain to receive help from the pump manufacturers, I made new valves as shown at C. Stems without heads were made to come within ⅛ in. of the top of the discharge chamber cover when it was bolted down. Steel helical springs were inserted between the cover and valve plate which surrounded the stem. The stems being long, the valve and valve plate could not drop free even if a spring broke. Only four springs have broken during the year the new type of valve has been in service.

Only one valve stem of the suction valves broke during a 12-yr. period, but when it did break it took a day to get the pump in operation again. The valve plate fell into the cylinder at the rear end and wedged



USE OF VALVE STEMS INDEPENDENT OF DISCS

between the follower and the bronze liner. The steam cylinder head had to be removed and the steam piston and rod pulled out. A rod sufficiently long to pass through the hole in the water piston was then made with threads cut at one end so that a couple of nuts could be screwed on while the other end was threaded 6 in. A piece of 4 by 4-in. hard wood having an iron plate with a hole through it for the rod was placed across the water piston head at its inner side and a washer and nut were placed outside of the outer head which was replaced temporarily on the cylinder so that when the nut on the outside was turned with a wrench the piston was drawn from its jammed position without further trouble.

Minneapolis, Minn. Fred S. Rutledge.

Power is defined as the rate of doing work and the common unit is the horsepower or 33,000 ft-lb. per min., that is, 33,000 lb. raised one foot in one minute or 550 lb. raised the same distance in one second. This unit which appears to be arbitrary is said to have been determined by James Watt and is based on actual tests. In trying to introduce his steam engines for pumping service at mines, he was asked how many horses his engine would replace. Tests with horses for long periods seemed to show that a horse traveling 220 ft. per min. could haul up out of a vertical shaft a weight of 100 lb. To be sure of good measure, Watt increased his measurements by 50 per cent and arrived at the figure 33,000 ft-lb. per min. as a fair measure of service of his engines.

Refrigeration Power Calculation

WHAT IS THE actual indicated horsepower required per ton of refrigeration per day under the following conditions? Condenser pressure is 176 lb. g., suction pressure is 25 lb. g., suction gas is dry and saturated and volumetric efficiency is 85 per cent. M. M. B.

A. This problem requires more data to make a correct solution possible. The compressor discharge temperature as well as the condenser pressure on the discharge or high pressure side should also be given. For example, if we assume the gas to be merely dry and saturated after compression (a rather impossible condition) the resultant assumed discharge temperature would be 93.5 deg. F. If we assume that the compression, from a point of 25 lb. g. with a dry and saturated suction gas, is adiabatic, then the discharge temperature would be 212 deg. F. In other words, the ammonia would be superheated an amount equal to the difference between 212 deg. F. and 93.5 deg. F. or 118.50 deg. F. In actual operation, the discharge temperature would fall somewhere between these two limits depending upon operating conditions and machine characteristics.

Temperature of the liquid ammonia just before it enters the expansion valve is also desirable to be known in the solution of this problem. We can assume that the condenser does not cool the gas to a point below its liquefying temperature at 176 lb. which is about 93.5 deg. F. or we can assume the ammonia to be sub-cooled considerably below this temperature. If it is sub-cooled, the resultant refrigeration per pound of ammonia pumped will be increased and the horsepower requirements per ton of refrigeration will be reduced.

Assuming adiabatic compression and no sub-cooling at the receiver, our solution will then be as follows:

The suction gas, dry and saturated at 25 lb. g. has the following properties: Entropy = 1.313, and total heat = 615.3 B.t.u. The discharged ammonia gas at 176 lb.g. at a constant entropy of 1.313 has the following properties: Entropy 1.313, total heat = 712.3 B.t.u., temperature 212 deg. F. The heat added by compression to each pound of ammonia will be, therefore, 712.3 — 615.3 = 97 B.t.u.

At 176 lb. g., ammonia will be liquefied at 93.5 deg. F. with a heat content of 147 B.t.u. The refrigerating effect of a pound of ammonia will be, therefore, the difference between the heat value of the liquid ammonia entering the refrigerator or 147 B.t.u. and 615.3 B.t.u., the heat value upon entering the compressor suction, that is 615.3 — 147 = 468.3 B.t.u.

One ton of refrigeration is equal to the removal of 200 B.t.u. per min.

Since each pound of ammonia gives a refrigerating effect of 468.3 B.t.u. it will require as many pounds of ammonia to be circulated per ton of refrigeration as 200 ÷ 468.3 = 0.427 lb. If 0.427 lb. must be circulated per ton refrigeration per min. and each pound compressed requires an addition of 97 B.t.u., the heat of compression added per ton = 0.427 × 97 = 41.5 B.t.u. per min.

One horsepower is equal to 42.5 B.t.u. per min. The theoretical horsepower required will be then 41.5 ÷ 42.5 = 0.977 hp. If the machine considered has a volumetric efficiency of 85 per cent, the indicated horsepower would be 0.977 ÷ 0.85 = 1.15 hp. This would be on the compression end. On the steam end there will be the additional load due to mechanical losses. If we assume the mechanical efficiency to be 88 per cent, the indicated horsepower on the steam end would be 1.15 ÷ 0.88 = 1.31 hp.

Solution of problem, assuming that radiation reduces the discharge temperature to 190 deg. F. and that the ammonia is sub-cooled at the receiver to 86 deg. F., is as follows:

As before, the suction gas will have the following properties: Entropy 1.313, and total heat 615.3. Under these new conditions, the discharge gas will have the following properties: Entropy 1.2912, and total heat 698.7. The heat added by compression to each pound will be, therefore, 698.7 — 615.3 = 83.4 B.t.u. The heat content of the ammonia, sub-cooled to 86 deg. F., at 176 lb. g. is 138 B.t.u. The refrigerating effect will be the difference between this heat value and the heat value of the gas at suction = 615.3 — 138 = 477.3 B.t.u.

Since the removal of 200 B.t.u. per min. = 1 t. of refrigeration, it will require as many pounds of ammonia to be circulated per ton under the foregoing conditions as 200 ÷ 477.3 = 0.42 lb. Since the compressor added 83.4 B.t.u. to each pound of ammonia pumped and it is necessary to pump 0.42 lb. of ammonia per t. of refrigeration, then for each ton of refrigeration it will necessarily require 0.42 × 83.3 or 35 B.t.u. of heat energy every minute of operation per 24 hr.

But, 1 hp. = 42.5 B.t.u. of heat energy per min. then 35 ÷ 42.5 = 0.827 hp., the theoretical amount required at the piston at 100 per cent volumetric efficiency. At 85 per cent volumetric efficiency, it would require 0.827 ÷ 0.85 = 0.975 hp. This assumes that the compressor itself runs frictionless and without losses. If the compressor itself is averaging 88 per cent mechanical efficiency, the actual indicated horsepower required will be 0.975 ÷ 88 = 1.12 hp. per t. of refrigeration.

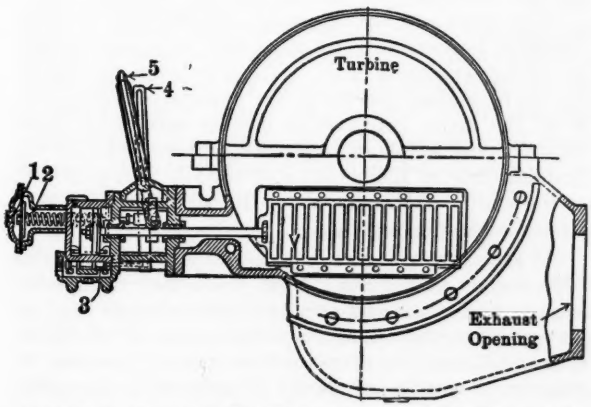
If this machine is motor driven, the electrical losses and friction losses of the motor must be accounted for. If the motor overall efficiency was 85 per cent, the motor consumption per ton of refrigeration would be 1.12 ÷ 0.85 = 1.32 electrical hp.

Bleeder Turbine Regulation

PLEASE EXPLAIN the action of a turbine governor in connection with a bleeder steam turbine. J. D. H.

A. Steam bled from a turbine may be controlled by hand or automatically. Hand-valve control is satisfactory, if the steam bled is practically constant. If it varies considerably and at frequent or irregular intervals, automatic control is the better arrangement. The principles of the automatic control of a Kerr turbine are illustrated.

A specially designed bleeder diaphragm equipped with a grid valve V controls the amount of steam passing through the low-pressure stages. The movement of this grid valve is regulated by the steam pressure in the heating system, which receives the steam bled from the turbine. A small pipe connection from the receiving system to the opening marked 1 in the illustration acts



BLEEDER CONTROL AS ACCOMPLISHED IN KERR STEAM TURBINES

upon a regulating diaphragm which serves as a pressure governor. Movement of this diaphragm is caused by the steam pressure and resisted by a coil spring, 2. Should the pressure in the heating system increase, the regulating diaphragm moves to the right against the pressure of the spring. The motion of the diaphragm is transmitted to a lever 4 pivoted at its upper end to a second lever, 5, and having its lower end attached to an oil pilot valve, 3. Movement of the pilot valve admits oil under pressure to the pilot cylinder, which in turn moves the piston and the grid valve, permitting an additional amount of steam to pass through the last stages of the turbine, thereby reducing the pressure in the heating system to normal. By the connection of lever 5 to lever 4, the movement of the piston rod changes the position of lever 5, returning the pilot valve to its neutral point.

Should the pressure in the receiving system fall, owing to a sudden demand for steam, pressure on the regulating diaphragm decreases and the spring forces this diaphragm to the left. By the connection of lever 4 to the diaphragm, the pilot valve is moved to the right, admitting oil to the pilot cylinder and moving the piston to the left so as to close the grid valve. The closing of the grid valve permits less steam to pass through the low-pressure stages of the turbine, consequently forces more steam through the bleeder outlet into the receiving system, thereby raising the pressure to normal. The motion of the piston and lever 5, together with increased pressure on the regulating diaphragm, returns the pilot valve to its neutral position as the pressure in the heating system becomes normal.

When the pressure in the heating system builds up to its normal point and a greater amount of steam is required to develop the rated capacity of the unit than is needed in the receiving system, the balance is passed through the last stages of the turbine, doing useful work. The turbine is also equipped with a nonreturn valve installed on the bleeder outlet. Should the flow of steam from the turbine to the heating system reverse, the steam will carry the valve up against its seat and stop the flow into the turbine. If, for any reason, this valve should fail to close, the speed of the turbine would increase to 10 per cent over normal, at which point the emergency governor would act and forcibly close the valve.

In some cases, an automatic pressure-reducing valve is installed on the bleeder outlet to permit proper bleeder-pressure control over a wide capacity range. In such cases, the nonreturn valve described above is replaced by an oil-operated combined nonreturn and pressure reducing valve, which is provided with the same nonreturn and emergency tripping features as previously described but with the additional reducing mechanism. A vacuum breaker, actuated by the emergency governor, is installed on the exhaust end of the turbine, to prevent overspeeding due to low-pressure steam backing into the turbine.

At times, when the turbine requires more steam to develop the power load than is needed in the heating system, the grid valve opens and permits low-pressure steam to pass into the vacuum stages. The extra power thus developed enables the turbine to carry the load with less steam, so that the governor shuts off a portion of the supply entering the turbine. This action of the governor, together with the admission of steam into the last stages, cuts down the quantity of steam entering the heating system and maintains it at the desired pressure.

Boiler Blowdown

FROM MY experience, I disagree with the answer to C. E. D's question in Nov. 15 issue. If the boiler is blown down before firing up the boiler, scale and sediment will be left in it. This can be demonstrated by putting muddy water in a wash stand and allowing it to settle. Upon removing the plug, the water will flow out with a whirlpool action, leaving the sediment in the bowl. If the water is agitated sufficiently to cause the mud to mix with the water, it will be carried off. Now, if the boiler is started sufficiently to cause the water to agitate the sediment in the boiler, more sediment will be carried away than if the boiler is blown down before firing or starting the boiler so as to cause a movement in the water.

Westville, N. J. R. W. CATER.

We would be glad to have the ideas of others who have had experience along this line.—Editor.

A CORKSCREW welded to the end of an ordinary right-angled packing hook increases the usefulness and efficiency of the tool greatly.

Editorial Comment

To Our Friends—A Year of Prosperity

Somehow, in spite of all reason, we humans are prone to picture a great impenetrable curtain hung between the close of one year and the beginning of the next. Fictitious though it is, our minds look upon this curtain as separating the events of one year from those of the next, as though the chain of events that make up history were separate links instead of overlapping and interwoven into an inseparable pattern. As the new year approaches, we gather in the reins of our affairs as though we were nearing an extremely narrow road with disaster on either side. Once through the gap, our nervous strain is relaxed and calm is restored, the reins are slackened and we resume our easy going ways.

Each year, we go back over our records and compare them with previous records; we take inventory of stock on hand; we determine growth in the past and estimate expectations, pay dividends on stock and interest on our bonds; we make out a budget for the coming year, plan extensions, renew insurance policies and other yearly contracts and in general clean the slate for the next series of problems.

All this review of the past and preparation for the future calls for the best that is in us both in quantity and quality of work. The results, however, are well worth the effort, for the more we accomplish the better prepared we are to accomplish still more and the more carefully we prepare for the future the fewer changes we shall be compelled to make in our plans.

As we view the past accomplishments in the power plant field, we feel perfect confidence in the future. The growth in the use of manufactured power has been steady; efficiency of equipment has also shown a steady increase; working conditions in power plants have, in general, improved, with the result that the power plant offers a more attractive occupation than in past years. Evidences are at hand pointing to healthy growth for the coming year and to you, our friends, whose activities are in our field of industry, we extend our hope for your prosperity and the happiness which it may bring during the coming year.

Will Power Plant Pressures Decrease?

Developments in power plant engineering during the past few years have been phenomenal and are reflected in the rapid rate at which the production of power per pound of coal has increased. Indications are that the curve of station heat rates is flattening out, however, and that further substantial gains must be made through some new developments.

These may take the form of increased pressures or increased temperatures. If numbers mean anything, it does seem that those who have pinned their faith on 1200-lb. plants are literally dragging the field behind them. With 750 deg. F. temperature limits, 600-lb. plants seem to have been definitely dropped and pressures in the range between 400 and 1200 lb. abandoned for the present.

In spite of the abundance of 1200-lb. construction, however, high temperatures have not been entirely forgotten. Theoretically, high temperatures offer greater advantages than high pressures and the policy of at least one company in standardizing on 400 lb. pressure for its system load and at the same time carrying on intensive research in the high temperature field is not entirely without support.

Five years ago, the utilization of 1000 deg. F. steam appeared impossible, little more than a dream, in fact, but today engineers wait, without voicing an opinion but with intense interest in the experiments going on. With the many installations now in service or under way, the next couple of years should prove definitely the practicability of 1200, 1800 and 3200-lb. plants as well as the ability of present metals to withstand 1000 deg. F. total steam temperature.

If metals can be produced capable of withstanding 1000 deg. F. and cheap enough to be used for general construction where subjected to these temperatures, we may see a pressure shift downward to the 400 to 600 lb. range, followed later by another gradual increase in pressure as metals are finally brought up to the point where both high pressures and high temperatures can safely be held.

The Modern Show Boat

Due to the recent shortage of water power in the northwest, the navy has been asked to allow the air craft carrier, Lexington, to augment the power supply of at least two cities. The Lexington with a 212,000-hp. power plant would be a valuable addition to even our largest power systems during periods of peak load. A 150,000-kw. station is not considered a negligible factor even in this day of 200,000-kw. units.

Since the Navy is reported to have granted the request, it opens up interesting speculation as to the possibilities of such a mobile unit to act as a peak load or emergency power supply for widely separated seaboard or river districts where distances are too great for economical transmission of power over high-voltage lines.

Such a plan would be open to criticism because of the possibility of several districts requiring the services of the supply ship at the same time. Still, with some interconnection of adjacent districts the plan might be feasible for a number of the smaller companies or for a number of municipal plants.

Such a scheme is not, of course, limited to ships or to large units. The Diesel unit mounted on railway cars is not new and should be particularly valuable in the Mississippi Valley districts where floods so often cripple the power supply.

Series Synchronous Condensers

Low power factor is a condition in alternating current circuits against which the electrical engineer and operator must forever be on their guard, for it is one of the most prolific sources of electrical loss. As pointed out elsewhere in this issue, in the small plant low power factor can be corrected by proper attention to the loading of motors and by the use of static condensers. Synchronous motors are also of value and may be used where this type of drive is suitable.

On long transmission lines, the effect of power factor is particularly noticeable and has long been a principal factor in limiting the amount of power which can be transmitted over a line. More specifically, assuming a fixed maximum voltage and load power factor, it is the total series reactance of the system that determines the amount of power that can be transmitted. An understanding of this principle combined with the necessity of maintaining constant voltage at the load has led to the practice of operating synchronous condensers at the load end of the line. These condensers may be considered as a source of reactive kilovolt-amperes capable of compensating totally for lagging load power factor but only partially for line consumption of reactive kilovolt-amperes.

Some time ago in an attempt to test out a new idea, an installation of series capacitors was placed in operation on a transmission line. Such condensers provide a method of series inductive compensation which is direct and inherently automatic, since it supplies the reactive kilovolt-ampere energy to the line in the manner in which it is consumed. By means of such condensers, placed in series with the line, compensation for the line effects has been completely effected.

Since this method of line compensation seems to offer distinct advantages, a proposal has been made recently by Theodore Morgan, Assistant Professor of Electrical Engineering at Stanford University, to produce the same results by the use of electrical machinery, that is by the use of synchronous condensers instead of capacitors. Professor Morgan's scheme utilizes two machines, one a synchronous motor operated directly from the line and the other an inductive compensating generator, driven by the synchronous motor and delivering voltage opposite in phase angle to the voltage caused by the inductive reactance of the line.

Although this scheme has not yet been tried out experimentally and although it has not been worked out in all its details, it would seem that it has all the advantages claimed for the series capacitor method. The inductive compensating generator is connected to the circuit in such a way that it will not supply its storage of rotational energy to a short circuit as does a synchronous condenser operating under such conditions.

It is to be hoped that this plan may receive further attention and that it may be tried out experimentally at least. With increasing interconnection of systems, the requirements for reliable long distance transmission become more and more rigid and this scheme may point the way to the solution of a vital problem in power transmission.

Industrial Research

"Both in originality and quantity, America is leading Europe in research work. Students here live in an atmosphere of excitement for research which stimulates their activity. Young men are leading America's latest researches in important fields and, with their fine training, natural ability and well equipped laboratories, there is no limit to what they can do."

This statement by Professor Albert Van Hecke of Louvain University, Belgium, made in the offices of the Engineering Foundation, is quite contrary to public opinion in America; at the same time it gives encouragement to American scientists and engineers who have always had great respect for the research work done by the leading European investigators.

With scientific research in the lead, commercial application should follow. Unfortunately, the research type of mind is seldom combined with commercial ability in one individual and for this reason many scientific discoveries with commercial possibilities lie unused in the libraries and files of the discoverers for want of connection with the proper industrial concern. As a result of proper connections, laboratories financed by individual industrial concerns have, in several instances, pointed the way to revolutionary changes in commercial practice and placed these concerns in a leading position.

In lieu of a private laboratory, many concerns are financing investigations carried on in our universities and technical schools, while still others are supporting research through membership in trade associations that are directing research along lines in which they are interested.

All this work is enlarging our knowledge of scientific facts on materials and designs but it remains for the men in charge of operation to investigate the features of application of equipment. How can we obtain longer life of equipment, higher efficiency from given equipment, higher percentage of availability? These are problems of operation that can be solved only in the plant, by the same methods of research that are employed in the scientific laboratory and the study can be made just as fascinating, though perhaps not so spectacular. Much of the work of the National Electric Light Association is along these lines, the information so secured resulting in marked economy. Similar investigations might well be undertaken in industrial power plants under the sponsorship of one of the engineering societies. Such an undertaking would require the coöperation of many power plant engineers but the results would undoubtedly pay for all the inconvenience caused. Research is merely an earnest endeavor to determine and record facts heretofore unknown and the engineer of any plant can well afford to have at least one problem under investigation at all times.

Acknowledgment

For material incorporated in the Heat Saving Number of Power Plant Engineering, we take this method of acknowledging our indebtedness to various engineers, manufacturers, standard handbooks, U. S. Government publications, reports of research and other sources for many of the data used.

Fiftieth Annual Meeting of A.S.M.E.

PAPERS ON PERFORMANCE OF POWER PLANT EQUIPMENT CREATED GREATEST INTEREST AT MEETING HELD IN NEW YORK CITY

SO DIVERSIFIED have the interests of the American Society of Mechanical Engineers become that an extra day was required this year to transact the necessary business of the society and present and discuss the papers prepared for this occasion. Simultaneous committee and technical sessions started early Monday morning, December 2, and the program continued until Friday afternoon. This was the Fiftieth Annual Meeting of the Society and 2100 persons registered for the sessions. Two outstanding events of the meeting were the President's night on Tuesday and the Annual Dinner at Hotel Astor on Wednesday evening.

Elmer A. Sperry, retiring president of the Society, was unable to attend any of the meetings, as he was enroute from Japan where he attended the World Engineering Congress as head of the American delegation and where he was decorated by Japan with the Order of the Sacred Treasure, second class, in recognition of his services in the cause of Japanese-American friendship. In his absence, Vice-President E. A. Muller officiated. Secretary C. W. Rice was also in attendance at the World Engineering Congress and his duties during the sessions were performed by C. E. Davies, assistant secretary.

Two papers were presented at the meeting Tuesday evening. One by Edward E. Hunt, secretary of the committee on recent economic changes of President Hoover's conference on unemployment, brought out what he considered the salient features of the present business situation with particular reference to the effect on industry of the recent stock market crash. He concluded that industry today is assuming a sense of balance, evidences of which were apparent early in 1929 and are stronger today than at any previous time.

"Engineers in American Life" was the title of the second paper at this meeting and was presented by L. W. Wallace, executive secretary of the American Engineering Council, the co-author of the paper being J. E. Hannum, editor of Engineering Index Service. This paper was a report on an analysis made of the men and women named in "Who's Who in America" to compare the relative standing of engineers with members of other important professions. The paper presented an imposing array of figures segregating and classifying the 28,805 persons listed in Who's Who. Among the 2858 engineers and architects whose biographies appear there are, or have been, 10 governors, 13 members of Congress, two members of the Cabinet and one President of the United States. The authors concluded that the findings of this assay clearly show that engineers and architects are versatile, not narrow; internationally, not provincially minded; leaders, not followers; scholarly, not unlearned; cultured, not rude; humane, not cruel; lovers, not haters of mankind.

At this meeting, the report of the election of officers for the coming year was read by Thomas Norman. These are: President, Charles Piez, chairman of the board, Link-Belt Co., Chicago, Ill.; vice-presidents, Paul Doty, chairman of the board, Minnesota State Board of Registration, St. Paul, Minn., Ralph E. Flanders, manager, Jones & Lamson Machine Co., Springfield, Vt., Ernest L. Jahncke, assistant secretary of the Navy, Washington, D. C. and Conrad N. Lauer, president, Philadelphia Gas Works, Philadelphia, Pa.; managers, Harold V. Coes, Ford, Bacon & Davis, New York City, James D. Cunningham, president, Republic Flow Meters Co., Chicago, Ill., and Clarence F. Hirshfeld of research department, Detroit Edison Co., Detroit, Mich.

At the Annual Dinner where Dr. Harvey N. Davis, president of Stevens Institute of Technology was toastmaster, Dr. James Rowland Angell, president of Yale University was the principal speaker and dealt with topics pertaining to the education of engineers for careers in industry, research and education. Other speakers were William L. Abbott, past-president of the society, Charles Piez, president-elect of the society and Dr. Oskar von Miller, director of the Deutsches Museum of Munich, Germany.

Among the technical papers presented, there were an unusually large proportion that dealt with the performance of equipment in industry. This effort of leading engineers to improve performance of all types of equipment in industry is a trend of thought welcomed by all men in industry as a means for reducing costs, promoting safety and conserving resources. Several papers of special interest to men engaged in the generation of power are abstracted here.

Operating Characteristics of Large Boilers

Tracing the development of the boiler plant from a number of small units operated at moderate capacities to the present plan of a few large units run at high rates of evaporation, Frank S. Clark, Consulting Engineer with Stone & Webster Engineering Corp., presented a paper under the above title, giving the conditions that limit the sizes and output and showed how, as the demand for larger units increases, these conditions have been overcome.

He pointed out that the effect of large units has reduced the size of buildings to house them and also the amount of auxiliary equipment to serve them. The effect of reliability of equipment on increased service factors was pointed out with the consequent reduced necessity for spare equipment. The governing factors in investment costs in a given condition, he stated, are the size of the unit, and the output obtainable, the former depending on the ability to manufacture and the latter on the fuel that can be burned in the furnace and the ability of the unit to absorb the heat.

The paper discussed further the proportioning of the heat absorbing surfaces between boiler, economizer and air preheater to obtain the most economic results at minimum cost and also the effect on operation of large units run at high capacity and in turn their effect on labor and maintenance costs.

With the increasing demands for boilers of larger and larger steam generating capacities, the development has been such that there are in operation in this country a number of boilers with steaming capacities of over 400,000 lb. per hr. each, with some few on order or being erected whose output will be upward of 800,000 lb. per hr. This increase in steaming capacities has been accompanied by increases in steam pressure and temperature which with greater efficiency of steam utilization have decreased greatly the amount of steam required per kilowatt-hour of electrical energy produced.

For a given condition, investment costs for a boiler plant are determined largely by two considerations: Size of individual steam generating units and output obtainable from each unit. The first has as its maximum limits the ability of the manufacturer to produce the units and as a governing limit, the relation of the individual units to the plant as a whole, to the characteristics of load and to the spare units deemed necessary to provide reliable and continuous operation. The second is governed by the fuel that can be burned in the furnace and the ability of the unit to absorb heat for the production of steam.

The size and number of boilers affect the cost not only of these units themselves but of the equipment that goes with them and of the building that houses them.

Within the limits imposed by their operation characteristics, the selection of a size and arrangement of heating surface for each type of equipment must be such as will give the desired overall results for a minimum of cost. For the riveted type, which can be used for pressures up to 700 lb., it is possible to obtain drums accommodating 60, 4-in. tubes spaced 7¾ in. between centers with only end suspensions necessary, giving a furnace width of about 39 ft. For pressures involving the use of forged drums, the limit is the size of the ingot from which the drum is forged. At present, this would allow a furnace width of about 43 ft.

J. B. Crane, in the discussion of this paper, stated that high-pressure boilers are less efficient than low-pressure boilers. He also stated that by proper arrangement of heating surface it is possible to reduce the heat absorbing area by 50 per cent. D. S. Jacobus thought that the advantages are all with large boiler units.

Recent Instances of Embrittlement in Steam Boilers

Under the above title, Frederick G. Straub of the University of Illinois, discussed briefly the cause of the recent boiler explosion at Crossett, Arkansas, attributing the failure to embrittlement produced as a result of using soda-ash treatment on a water too low in sulphate content. Other instances of cracking of seams in steam boilers are also described. Emphasis was placed upon the regular inspection of leaky seams in steam boilers, particularly when the boiler water does not meet the A. S. M. E. recommendations.

The data from the embrittled boilers cited show that the cracking took place in boilers made by practically every large boiler manufacturer. It also occurred in seams subjected to high temperature as well as those entirely away from the heated area. Boilers receiving excellent fabrication cracked just as readily as those not so well made. Most of the cases were detected before it was too late, as the results of the timely inspection. A few had reached the dangerous stage due to the fact that no attention was paid to the type of water in use. It was not realized that waters not embrittling in nature may be readily made so by certain methods of water treatment.

J. C. McCabe expressed the opinion that the author did not analyze all cases properly, as, in some of the cases reported, he thought the designer and fabricator as well as the water were to blame for failures. He reported on cases which he had examined where poor metal and vibration fatigue were the evident causes of failure. Dr. McAdam would emphasize other phases of stress and cycles as common factors in boiler failures. He stated that he had found cases where boilers had failed under stress and corrosion with good water. It may, he thought, be advisable to change the carbonate-sulphate ratio in boilers with changes in stress. A. A. Adler recommended inside calking and bending plates while hot as an inhibitor of embrittlement. W. H. Owen thought stress had more to do with embrittlement than caustic boiler water and that faulty installation will set up unnecessary stresses. H. A. Robins commended the author for keeping the subject before engineers for discussion. A. D. Bailey thought it an advantage to have the problem attacked from every possible angle.

BUILDING AREAS AND INVESTMENT COSTS OF BOILER PLANTS

Number of boilers	4	6	8	12
Sections per boiler	60	40	30	20
Relative building area, per cent	100.00	112.00	127.00	133.00
Relative investment cost per cent	100.00	112.00	124.00	142.00
Proportional cost of main items of construction and equipment:				
Building and foundations	16.10	16.50	16.70	17.10
Boilers, superheaters, settings, etc.	32.00	33.00	34.60	38.00
Draft and feedwater systems	22.40	22.40	22.00	19.80
Piping	9.60	9.50	9.20	9.00
Fuel and ash handling	7.60	7.40	7.20	6.70
Fuel preparation	9.60	8.60	7.90	7.00
Auxiliaries	2.70	2.60	2.40	2.40
Totals	100.00	100.00	100.00	100.00

Performance of Modern Steam-Generating Units

To determine those factors which seem to be the most responsible for steam-generating-unit outage is a problem which always arises when a plant is being designed for a certain capacity factor, where the reliability or availability of the boiler units must be accurately foreseen. In order to get a basis on which to solve such problems, C. F. Hirshfeld and G. U. Moran, both of the research department of the Detroit Edison Co., conducted an investigation of boiler plants and reported the results in a paper under the title given above.

Some have held that the outage increases directly with the severity of use. Others contend that the method of burning the fuel has a definite bearing on reliability. Still others have set different values for unit reliability on different kinds of fuel.

A study of the facts obtaining in the power-generating industry was made along the same general lines as the steam-turbine investigation made by the Prime Movers Committee of the N.E.L.A. The methods used in collecting information were as nearly identical as circumstances and the character of the units studied

would permit. Daily operation logs were filled out for the period of one year by the operators of some 200 boilers scattered about the country in 60-odd stations. The data resulting were compiled by one group of men in such a manner that the results might be readily compared. These compilations were shown in both tabular and graphic form.

The units were arranged in groups or classes according to methods of fuel burning and the working steam pressures, and then numbered in order according to their average rates of evaporation. With the data arranged in such a manner it has been possible to arrive at some rather definite conclusions.

It may be said, in general, that the results thus far deduced indicate that details of design and construction and operating skill are far more important in obtaining a high availability factor than are such things as rate of output per unit of surface, type of fuel, method of firing, and many of the other factors which have been widely discussed in this connection.

Study of the diagrams and charts indicates that boiler outage is not proportional to severity of use. In fact, it happens that the figures show more outage for many boilers working at a low rate of heat transfer than for those working at comparatively high rates for which data happened to be obtained.

If taken at their face values, the results obtained would indicate a slight increase in availability with increasing severity of use. If this be the fact, it is reasonable to suppose that it follows from more careful design and operation in the case of equipment which is driven at the higher rates. The diversity of performances at substantially similar rates of output per unit of surface and per unit of furnace volume would seem to confirm such an interpretation.

There is no clear evidence of the superiority of either of the recognized methods of firing coal. Points representing stoker firing and pulverized-fuel firing are so to indicate that design and operation are undoubtedly of far more significance with respect to availability than is the method of firing adopted.

In discussion of the paper, J. H. Lawrence said that the use of water-cooled furnace walls has notably increased the availability of boilers in East River Station. He thinks boilers of modern design have a higher availability factor than turbines. W. L. Abbott considered coal quality an extremely important factor, as the necessity for more frequent cleaning with some coals will add to the outage periods. Henry Kreisinger commended the paper as a start in establishing a standard of availability, the average for the plants studied being 85 per cent.

Service Characteristics of Diesel Engine Lubricating Oil

Diesel engine lubrication has presented difficulties, owing to the high compression pressures and the high temperatures and the great weight of engine parts. This condition led the authors of this paper A. E. Flowers and M. A. Dietrich, both of the De La Vergne Separator Co. to make a study of progressive records and the characteristics of lubricating oil used in a Diesel engine in regular service for about a year, installed in a freight switching locomotive running 23 hr. a day. Service records of operating experiences usually have shown that the lubricating oil may cost from 10 to 25 per cent as much as the fuel oil.

Fuel dilution may come about in small part as direct leakage past the piston rings, but it would seem that this is negligible except when for some reason some cylinder fails to fire. Fuel dilution may also result from pipe or pipe fitting breakage, gasket leakage or spillage around the engines.

When the sludge is removed at the same rate as it is produced, the sludge content of the oil, after filling the crank case with new oil, rises during the first part of the run and then stabilizes at a moderate value which is only as high as may be needed for the time and heating required to agglomerate the sludge to the settling and separating point.

It may be desirable to remove the oil because of some accidental occurrence such as fuel dilution, as in some of these runs, or the need for complete overhauling of the engine. When removed, the oil may be given a simple but very effective treatment for reclamation including a readily applied method for taking out fuel dilution if any be present.

The sludge that separates from Diesel engine lubricating oil is mainly carbonaceous matter. From a new engine, however, large amounts of free iron and sand may be found. The carbonaceous matter is absent from new oil at the start of a run, reaches a maximum after several hundred hours, and then decreases or remains practically constant at values of 0.5 to 1.5 per cent of the volume of the oil.

Advantages of Cleaning Oil

Although oil may be saved by continuous clarification, it is not thought that this constitutes a measure of advantage but that the reduction of varying wear is far more important. Batch reclamation may be useful where the engine must be completely overhauled or where some accident has contaminated or damaged the oil or where fuel or other dilution has occurred. Especial tests have shown that heating and allowing a settling period, definitely assist in agglomerating the sludge to a point where it is readily removed. Other tests have shown that washing with clear boiling water and then removing the water and sludge together in a centrifugal separator tremendously improves the centrifuging process, allowing purification through-put rates about 100 times greater than purification with water washing. Such simple treatments will restore all the original properties except color and to some extent neutralization number.

The fuel oil dilution, if any, may be removed by heating and blowing steam directly through the oil. The high temperatures in use for superheated steam greatly reduce the time required and the steam consumption needed for fuel dilution removal.

H. C. Dinger, in discussing the paper, stated that the contamination to be expected is much less than with gasoline engines because of the absence of the light ends. The following conclusions were drawn from the examination of a large number of used Diesel engine lubricating oils from U. S. submarines, the submarines being equipped with centrifugal purifiers:

(a) A slight increase in specific gravity of the oil.

(b) A considerable decrease in flash point in both open and closed cup apparatus.

(c) A considerable decrease in fire point.

(d) Pour point not much affected.

(e) A slight decrease in viscosity.

(f) The oil is darkened in use but not to nearly as great an extent as encountered in internal explosion engines (gasoline engines).

(g) No development of mineral acidity in the oil.

(h) Neutralization number, precipitation number and carbon residue are increased to practically the same extent as encountered in a force feed turbine lubricating oil system.

(i) The nature of the carbon residue in the oil is not changed, nor is there any appreciable increase in ash.

(j) The non-emulsifying properties of the oils were considerably affected.

(k) Not any of the samples contained more than a trace of water.

These tests show that centrifugal purification of the lubricating oil of Diesel engines is fairly satisfactory and that complete renewal is necessary only at special times when a complete cleaning of the crank case is desired.

Eugene P. Kiehl reported that "the sludge as removed from our separator has the consistency of soft rubber and carries with it approximately 50 per cent of oil. The quantity of sludge produced and removed on these 840-hp. engines amounts to approximately 6 per cent of the makeup added."

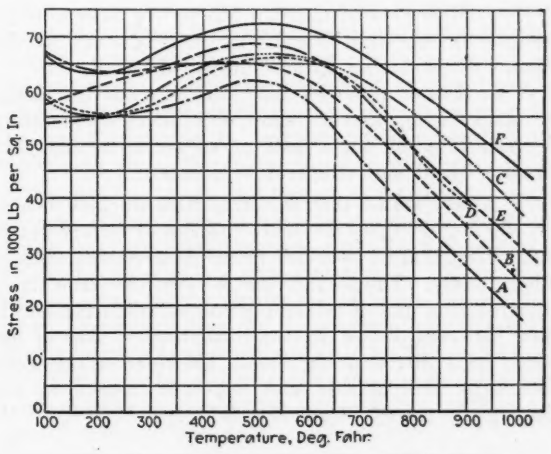
Working Stresses for Steel at High Temperatures

That the safe working stresses for the shells of boilers and pressure vessels have been determined to a greater extent by experience in the use of such vessels under actual operating conditions than by any theoretical uses was a statement by D. S. Jacobus, advisory engineer of the Babcock & Wilcox Co., in his paper under the above title. These stresses are ordinarily based on the average stress in ligaments between tube holes or the like. This is an approximate method. On the one hand, the stresses in the metal at the sides of a hole in a drum which is stressed within its elastic limit, may be twice or over the average stress in the ligaments or in the solid plates where a single hole is placed in a seamless shell. On the other hand, the ductility of the steel causes the stresses to be different after the drum is placed in service from stresses when the drum is subjected to the initial pressure, the general effect being to cause the stresses to be more uniform under working conditions than on the initial application of the pressure.

That the service conditions have much to do with the pressure at which a vessel can be safely operated, may be seen on considering a seamless cylindrical drum having a hole drilled in its shell. If such a drum is subjected to a gradually increasing pressure, the pressure at the sides of the hole of, say twice the average stress in the boiler, will cause the stress in the metal near the hole to exceed the elastic limit when a certain pressure is reached. On increasing the pressure still further, the yielding of the metal will result in a permanent set in the metal and will cause a redistribution of the stresses in the metal.

If the pressure is relieved, there will be stresses near the hole due to the set in the material and if the pressure be high enough, these stresses are such that on applying and relieving the pressure a number of times the material will fail at the hole through a fatigue action. The safe working pressure for a drum of the sort would therefore be much higher for service conditions where it would be subjected to a reasonably steady pressure or where the pressure would be only occasionally applied and released than it would be if used under a continually fluctuating pressure.

Another question to consider is the distribution of strain due to the thickness of the walls of the vessel which causes the stresses on the inside of the shell in a thick walled vessel to be greater than those on the outside when the stresses are within the elastic range of the material. With ductile material, the stresses will be more or less equalized from the inside to the outside of a thick drum on increasing the pressure to a point



TENSILE STRENGTHS FOR CARBON STEELS

(A, 0.13-C steel, White, Eng. Res. Bull., Univ. of Mich., 1923; B, 0.17-C rolled bar, Valve World, August, 1923, p. 269; C, 0.17-C firebox steel, French, B. S. Tech. Papers, 219, p. 692; D, 0.19-C firebox steel, French, B. S. Tech. Papers, 219, p. 691; E, 0.24-C steel, Proc. A.S.T.M., vol. 25, p. 39, fig. 3; F, 0.25-C marine steel, French, B. S. Tech. Papers, 219, p. 690.)

where the proportional limit of the highly strained parts of the material is exceeded.

Another factor which results in strain to material of a shell, which must be considered in establishing the working stress, is the effect of heat applied to the outside of the shell and transmitted to the inside of the shell.

Results secured in practical experience are used for setting the maximum working stresses up to temperatures of 800 deg. F. and for temperatures above 800 deg. F., working stresses are scaled down in proportion to the falling off of the stresses that produce creep. The effect on the stress of piercing a boiler shell with holes and of transmitting heat through the shell, was discussed in the paper, as well as the tendency toward equalization of stress through extension of the most strained fiber.

It is hard to formulate a rule, the author stated, that should be generally applicable for determining the working stresses at high temperatures, as the conditions which enter each case must be considered. A variation in temperature has a great effect on the rate of creep and in some cases it is hard to establish the temperature of the metal, such as in those where heat is transmitted

through the metal to the inside of a vessel. It was the hope of the author that the working stresses used for steel of high temperatures by different parties will be submitted in order that all may get together in establishing a rule that will represent good practice.

L. H. Norton expressed the need for information on distribution of stress under plastic conditions. Also on the creep of steels at lower rates in order to determine how the rate of creep falls off with the load and whether there is any limit below which plastic flow ceases. Massachusetts Institute of Technology is now conducting tests on creep, he stated.

Albert Sauveur agreed with the author that a closer relation exists between the creep valve of a steel and its tensile strength than between the former and the elastic limit and cited tests on austentic and non-austentic steels.

H. F. Moore stated that the attempt to determine an absolute "creep limit" seems as unsatisfactory as the attempt to determine an absolute elastic limit.

J. J. Kauter reported that studies made by Crane Co. upon "creep arrest" show continuous deceleration of creep rates on some tests of as much as one year duration—load and temperature constant.

N. Artsay stated that for structures working below, say, 600 deg. F. there are three theories of failure under load. First that of exceeded principal apparent stresses failed utterly. The second, that of exceeded true stress accompanying the maximum principal deformation is being superseded now by the third theory, that of exceeded maximum shearing stress. Considering the creep phenomena in structures with combined stresses, we are without any theory of strength whatever.

Power—Steam or Hydro or Both

Emphasis was placed, by William W. Tefft of the Fargo Engineering Co., in his paper on the above subject, on the necessity of including all pertinent factors in comparing steam with hydro power, drawing attention to the fact that any conclusions based upon a part of these factors will be erroneous, misleading and valueless. In considering the various factors that go to make up the final conclusion, attention is called to the superiority of steam power where need for power is immediate, where the more profitable hydro sites have already been developed, and where the actual load factor is very high. It is also made clear that hydro power is superior in reliability and as reserve capacity and can operate to advantage at a much lower load factor than can steam. It might be said that the paper deals largely with load factors. Curves based upon a large number of developments in each case indicate that usually for 60 per cent load factor or less, the hydro plants are superior, the statement being made that no steam plant can now be built for 25 per cent load factor that will produce current for one cent per kilowatt-hour, but there are many water power plants, most of them in fact, that can do this.

The author comes to the conclusion that there is ample proof that a power system combining both steam and hydro plants can generate power cheaper than either kind of prime mover for the same conditions, thus indicating the mutual advantage of one to the other.

Changing Requirements in Hydraulic Turbine Speed Regulation

Flyball control of units such as are now operated in the plants of large systems, stated Forest Nagler, hydraulic engineer with Allis-Chalmers Mfg. Co., may be of secondary importance for normal conditions. It is a control for large or sudden changes, a shut-down device for emergency purposes, and it effects certain conveniences in operation. It is of real use only in emergency conditions. It is entirely ineffective when a unit is on the load limit and it is entirely ineffective when the gate position is controlled by frequency under the gradual load change conditions. It comes into play in case of line troubles or when load changes are faster than the frequency control can meet.

Practically complete governing equipment can be built without a large flyball and with probable ultimate simplification of governing equipment. It would consist of frequency control operating the gate through regulating cylinders and distributing valve, a load limit positioning device for that valve, just as is done nowadays except that no main relay connections would be required, no dashpot necessary and all questions of flyball eliminated. The emergency stop and the emergency start would be obtained simply by making secondary contact at an abnormally high or low frequency point that would take the unit off the line or at least close it to "speed-no-load" condition.

It is not suggested that governors be eliminated. Many of their elements are very satisfactory. The oil pressure systems now in use are probably the best form of speed reducing mechanism for the purpose, reducing 600 to 1200 r.p.m. motor speed to as low as 1 r.p.m. It is suggested that they no longer be governors from a normal speed control standpoint with its possible wide range of gate movement. They should be control mechanisms designed for the duties that they are to accomplish. The design of such controls would rapidly modify governors as they are designed today and would also begin to modify turbine structures themselves, simplifying and cheapening them, a large portion of their cost being due to details which are not necessary or even desirable for production of maximum number of kilowatt-hours for a given stream flow or for a given amount of storage water.

J. P. Jollyman confirmed Nagler's conclusions that governors act on a rise in speed of ½ cycle. Turbine controllers are simpler than governors for small units and medium or high heads, therefore they are preferable for automatic or semi-automatic plants.

There is an increasing need for constant speed, said S. Logan Kerr, since many industries depend on constant speed to control their products. In selecting apparatus to control speed or frequency, there are three distinct elements which must be considered:

1. Rate and magnitude of load changes.
2. Capacity available and characteristics of governors.
3. Characteristics of load with respect to speed.

He does not look upon this very simple device as the best answer to all operating problems. The day has not come when the conventional governor action can be relegated to the past.

Increased Kilowatt Output of Adjustable-Blade Propeller Turbines

C. R. Martin, Engineer in the Hydraulic Department of Allis-Chalmers Mfg. Co., stated in his paper under the above title that the commercial development of the adjustable-blade type hydraulic turbine runner has been in a slow and careful manner with the idea first of solving its mechanical difficulties and later of taking full advantage of the possibilities of high efficiency. The principal problem of the engineer in introducing a new design is to keep to a safe and reasonable program of development, such as will not incur serious financial losses.

In addition to the mechanical difficulties of the adjustable runner, there have also been many problems of regulation to be solved as well as the determination of a correct design of draft tube. This paper covered the gradual development and placing in service of the adjustable-blade runner in the United States to the time when the European design of automatic adjustable-blade runner was brought to this country.

The objectionable feature of the fixed-blade type of propeller runner is the peaked efficiency curve and the low efficiency at part gate openings. By adjusting the runner blades, one can operate at all the peaked points of efficiency, reducing the disadvantage of part gate operation. It is now possible to obtain a peaked efficiency on a propeller type runner that is within one to two per cent of the peaked efficiency of Francis turbine runners. The blades of a Francis runner are not adjustable, resulting in one peak efficiency. The adjustable runner therefore with the possibility of adjusting its peak over a considerable range in load, makes it possible to obtain an average plant efficiency as high as that of the Francis runner and, in some cases, even higher over all efficiency can be obtained. The advantage of the adjustable-blade propeller runner lies in the increased kilowatt-hour output combined with lower over all costs.

Conference Adopts Skeleton Steam Tables

RESULTS of a conference of physicists and engineers engaged in the determination of the properties of steam, held during the week of July 8 in London, were made public at the A.S.M.E. annual meeting. This conference was convened by the British Electrical and Allied Industries' Research Association and was attended by representatives from America, Great Britain, Germany and Czechoslovakia. The American representatives were Dr. Harvey N. Davis, president of Stevens Institute; Dr. Dickinson, Bureau of Standards; Professor J. H. Keenan, Stevens Institute; George A. Orrok, consulting engineer, and Nathan S. Osborne, Bureau of Standards.

At the conference, it was agreed that the best form in which to present the recommendations would be to draw up in skeleton form, a small table of the properties of saturated and superheated steam. To determine each figure to be inserted in the table, suggestions would be made by each of the four countries represented and a mean figure would be adopted, together with a tolerance of an agreed amount. The skeleton table presented gives, for saturated steam, eight temperatures varying by steps of 50 deg. C. from 0 deg. C. to 350 deg. C. and the determination of the following properties for each temperature: Saturation pressure, specific volume of the liquid, specific volume of the vapor, total heat of the liquid and total heat of the vapor.

For superheated steam, the tables take a number of pressures varying from one atmosphere up to 250 atmospheres and give, for temperatures varying by intervals of 50 deg. C. or 100 deg. C., the specific volume and total heat of the steam. For total heat values, the international kilo-calorie was the unit used and was defined as equal to 1 kw-hr. divided by 860. In making conversions, the following values were used: 1 lb. = 453.5924 grams; 1 in. = 2.54000 cm.; 1 kg. per sq. cm. = 14.223334 lb. per sq. in.; 1 cu. ft. per lb. = 0.06243 cu. m. per kg.; 1 cu. in. per kg. = 16.0184 cu. ft. per lb.

The saturation pressure at 100 deg. C. is defined as being 1.0333 kg. per sq. cm. under standard gravity conditions. This is not an agreed value but a definition and as such needs no tolerance. It has always been the custom to define the total heat of the liquid or vapor as the heat content in excess of that contained by the liquid at 0 deg. C. and saturation pressure. This latter content is, therefore, zero by definition.

In deciding upon the figures to be inserted in the skeleton tables, based upon the various rational proposals due consideration was given to the method in which the figures had been determined. More weight was attached to the figures which were the result of direct experiment than to those which were merely an extrapolation from other work. The figures thus inserted in the table did not represent a mechanical averaging of the national figures, but were the result of very careful consideration of the relative values of the different proposals. In this way, the figures given in the table and the tolerances attached to each figure were obtained.

Those figures, for which it has been found necessary to allow a comparatively large tolerance, were recognized as presenting special difficulties and requiring further detailed experimental investigations. At a later conference, it is hoped that the range of national values for any one figure may be reduced and consequently the tolerances also reduced, and that values for a larger number of pressures and temperatures may be inserted.

Tolerances throughout the entire range of tables for both the saturated and superheated steam are well within the errors of practical application ranging from less than 0.1 per cent in most cases to a high 2 per cent at some of the high temperatures.

POOR RESULTS in coal washing and ore concentration are sometimes attributed to the presence of flat particles in the feed. In order to estimate the shape of particles in coal more accurately than can be done by visual observation, a screen scale consisting of a combination of square-hole and rectangular-hole sieves is being used at the Northwest Experiment Station of the United States Bureau of Mines. The smaller dimension of the rectangular-hole sieves is 75 and 50 per cent of the square-hole sieve with which they are used. Each square-hole sieve product is separated thereby into three shapes of particles which are called "cubical," "prismatic" and "flat."

Eighth National Exposition of Power and Mechanical Engineering

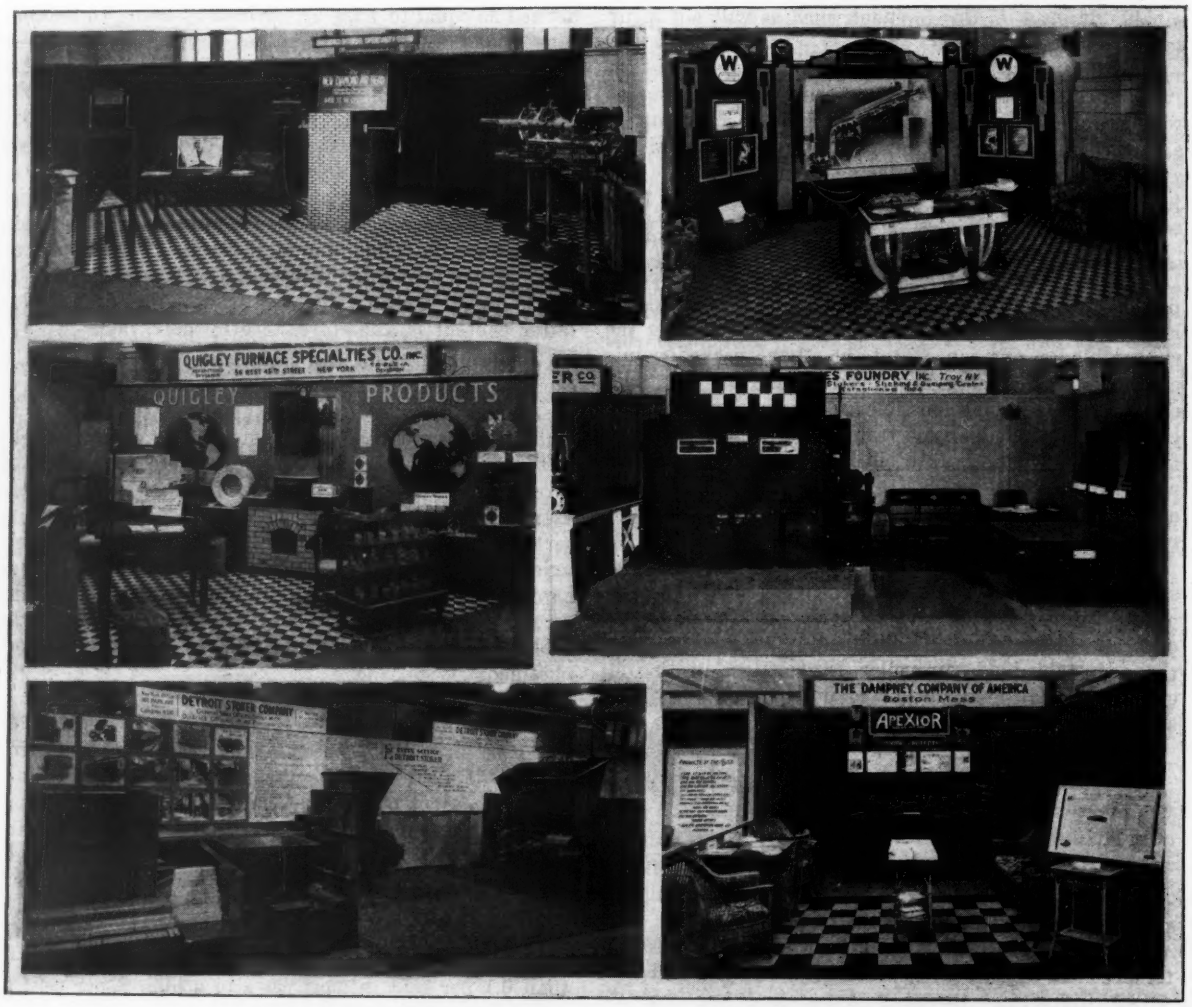
FROM DECEMBER 2 to 7 the Eighth National Exposition of Power and Mechanical Engineering was held in Grand Central Palace, New York City. Total attendance for the week, as estimated by the management, was approximately 125,000, while the total registration was estimated at 28,000. A total of 420 exhibitors displayed equipment.

New stokers, both for power boilers and of the smaller types for use with heating boilers, attracted attention of the visitors to the show. Trends toward use of high pressures in many plants were reflected in the displays of piping, valves, fittings and boiler construction for pressures of 1350 lb., and in some cases for 2000 lb. Water-cooled furnace walls, pulverized coal burners, combination gas and oil burners, feedwater treatment apparatus—all reflected the tendency toward high ratings and the demand for continuity of service.

Instruments, regulators and controllers of all types were shown for high pressure work.

Unit heaters, new forms of radiation and new methods of heat control were of interest to industrial and building engineers.

New designs of electrical control equipment were displayed showing how compactness and efficiency are secured not only in starters for 2-hp. motors but also in switching devices used in the largest central stations. Synchronous motors for many applications and motors designed to run under most adverse conditions of dirt and fumes were in evidence. Prime movers in the form of gasoline engines and small turbines were displayed. There was great interest in mechanical transmission equipment such as gears, chain drives, speed reducers



STOKERS OF VARIOUS CAPACITIES AND TYPES AND OTHER MATERIALS USED IN BOILER AND FURNACE CONSTRUCTION ATTRACTED ATTENTION

and belting. Many displays of tools for cutting and threading pipe, for welding and for working in both wood and metal attracted the visiting engineers.

Boilers and Accessories

The Babcock & Wilcox Co. showed a section of a 42-in. diameter, 2-in. thick, arc welded drum, designed for 1047 lb., subjected to 1,035,000 applications of pressure of 1570 lb. per sq. in., with no evidence of weld failure. A superheater section with multiple loop units was shown, designed for ease of cleaning. A complete ⅛-size model of a B. & W. cross-drum boiler with superheater, air heater, economizer, Bailey furnace and Westinghouse stoker was on display here. This model is to be in the permanent exhibit at the Smithsonian Institution.

Demonstration was made at the booth of Hall Laboratories of the method used by D. J. McAdam, Jr., in studies of corrosion fatigue at the U. S. Naval Academy, Annapolis, Md.

New air soot blowers were displayed by Diamond Power Specialty Corp. These are designed for straight through blow with pressure drop of less than 5 lb. When the blower element is rotated, a cam on the spindle opens a pilot valve that actuates the main valve, which is of special design to give low pressure drop.

Prat-Daniel Corp. announced that the Thermix air heater is to be handled for boiler applications only by The Babcock & Wilcox Co. Attention was also called to improved fans and rotors in the Thermix stacks, designed for high drafts and minimum wear from cinders.

O. E. Frank Heater & Engineering Co. showed a new heat reclaimer, consisting of a series of units hung vertically in a pit or tank, into which flows the water from which heat is to be reclaimed. Clean water to be heated flows through tubes of which the heat transfer elements are composed. The reclaimer is designed especially for laundries or similar applications where waste water is at 120 to 130 deg.

Combustion Equipment

On its multiple retort underfeed stoker, Detroit Stoker Co. showed a new power dump, actuated by a cylinder using water, steam or air. A triple-retort stoker with side cleaning was shown, designed for boilers from 300 to 500 hp. The Detroit Junior stoker for boilers from 30 to 100 hp. was also shown. This has built-in fan, air blast control, adjustable feed on coal ram, Timken roller bearings, rear tuyere and provision for side dumping. It can be operated automatically with a temperature or pressure control system and is motor-driven through a reduction gear.

Jones stoker with Riflex drive, as described in the March 1, May 15 and July 1 issues of Power Plant Engineering, was shown by Riley Stoker Corp. Riley Atrita, incorporating the new horseshoe-shaped casting with wearing plates, as described in the June 15 issue, was also shown, together with the latest flare type burner of turbulent type. A section of the Riley-La Mont water wall, as described in the April 15 issue, was also shown.

Working model of the link-grate, multiple-retort underfeed stoker, as described in the November 15 issue of Power Plant Engineering, formed an attractive background for the booth of Westinghouse Electric & Mfg. Co. A section of clinker grinder, removed after 5 yr. service at Devon Station, without renewal, was also featured. In another booth, the company featured a 150-hp. turbine and an interesting display of the action of the grid glow tube which would start the motors of a small airplane when the hand was brought near a large ball.

Grinding element of its new table mill was exhibited by Fuller Lehigh Co. This consists of three rings and two rows of balls. The upper and lower grinding rings are stationary and the center ring revolves, with the balls above and below it making contact on stationary and revolving rings. The balls themselves take the vertical thrust of the rotor, which is guided sideways by roller bearings. Pressure between rings and balls is adjustable from the top of the mill. Coal is fed by a drag feeder on the mill and drops down to a table inside and thence to the grinding surface. Pulverized coal is removed by air separation. The mills are being built for about 20–25 t. per hr. capacity. This company also showed a full-sized section of a corner of its slag tap furnace.

Neemes Foundry, Inc., called attention to improvements in its automatic stoker. Damper control has been simplified, gear reduction and motor unit made more compact, range of adjustment for coal feed increased. Method of feeding overfire air in manifolds over the door arches has been improved.

Application of Convey-O-Weigh, an automatic scale, was shown by Richardson Scale Co., in controlling supply of materials from one conveyor to another, weighing between, or in proportioning.

Engineer Co. displayed a combination gas and oil burner to give a capacity of as much as 2500 hp. per burner with 5 in. static air pressure. Either mechanical or steam oil burner can be used. The gas issues in a cylinder, air being swirled into it through vanes. When burning oil, the oil issues from the burner as a cone, mixing with the air coming through the vanes under forced draft.

Constant weight feeder, developed originally for its pulverizer, was displayed by Hardinge Co., Inc. It consists of a balanced, counter-weighed belt conveyor under a hopper from which material is fed. As the weight of the material comes on the conveyor it pivots the counter-weighted conveyor and, through a system of levers, controls the gate opening through which the material feeds. This feeder can be built for 100 lb. to 120 t. an hour capacity.

Combination oil, gas and pulverized coal burner was the feature of the Peabody Engineering Corp. display. This is designed so that change from one fuel to another can be made quickly. The burner is of the turbulent type, using only one set of furnace openings and one set of air ducts. A new combination gas and oil burner was shown, designed to fire 1000-3500 lb. of oil an hour or its equivalent in gas.

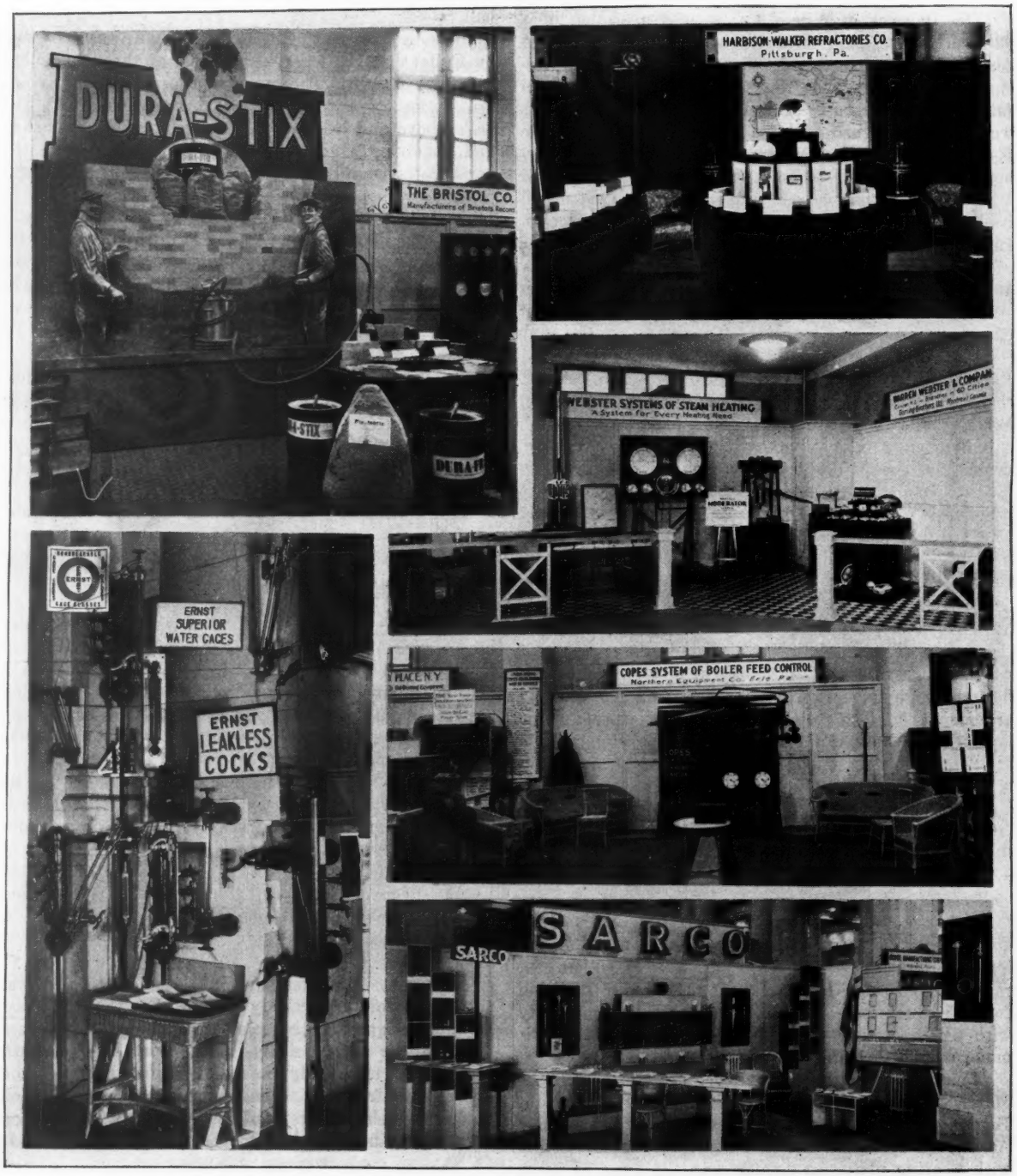
Thomas Grate Bar Co. displayed models of its new W-S-D grate for hand firing, designed to permit effective cleaning of fires and better combustion by a mechanism that provides for wiggling, shaking or dumping as conditions demand.

Conveying system for coal, lime dust and similar products was announced and shown by Allen & Billmyre Co., Inc. This consists of a conveying tube to convey the material to a suction tank from which it is discharged by a rotary discharger.

Meters and Instruments

Flush-type, rectangular-case recorders for panel mounting were shown by Brown Instrument Co. These are designed so that the entire operating mechanism of the meter rolls out the front of the case on a carriage to allow inspection, without stopping the mechanism. Attention was also called to the long distance pressure gage, operating on the inductance bridge principle.

Selsyn-operated devices for remote indication and record of liquid level flow, pressure, temperature, draft or other factors were a feature at the booth of Bailey Meter Co. Several types of transmitter are used. For pressure or liquid level, motion of a float is imparted to the rotor of a Selsyn generator. For transmitting vacuum indications, a U-tube is used with a float actuating the Selsyn through a rack and pinion. A draft indicator uses a draft bell, counter-weighted levers and sector to move the Selsyn. Other types using sylphon



EXHIBITS OF BOILER ACCESSORIES, REFRACTORY MATERIALS, STEAM HEATING SYSTEMS, TRAPS AND CONTROL DEVICES

bellows, amplifiers and so on were shown. All these transmit through an electrical circuit to the Selsyn receiver which is supplied in various types, 12-in. or 17-in., and with either round or rectangular case. Another feature at this booth was the new thermo-hydraulic feedwater regulator, as described in detail in the July 15 issue of Power Plant Engineering.

Heat flow meter for measuring heat flow through pipe covering or other heat insulation was shown by Weston Electrical Instrument Corp. Three thin rubber belts are strapped around the pipe, one belt containing a large number of thermo-couples. A milliammeter, which can be calibrated directly in B.t.u. per square foot per hour, can be used for determining the variations in electromotive force produced in the thermo-couples by the temperature differences caused by flow of heat between one side of the belt and the other.

At the Foxboro Co.'s booth, attention was called to improvements in the drive of the flow meter, which has also a new type of integrator. Crystal iron finish meter panels of new design were displayed. On indicating gages, a micrometer adjustment has been developed for pointers so they can be adjusted without removing them from the shafts.

For measuring and recording condenser leakage Leeds & Northrup Co. showed a new meter actuated from a conductivity cell in the condensate line.

Builders Iron Foundry showed a new long-distance indicator for the Venturi meter. On the main shaft of the Venturi meter is placed a pulley to drive a Selsyn generator, transmitting to a Selsyn receiver, at any convenient distance, that can be made to actuate an indicator or recorder.

Dial draft gages in 1, 2 and 3 pointer types were new products shown by Ellison Draft Gage Co. An air filter gage was also displayed on which a red line marking high draft readings shows when the filter needs cleaning. A new line of U-gages was displayed for use with small stokers and similar equipment.

Ernst & Co. displayed a new safety protector guard for standard tubular boiler gage glasses. This consists of a metal shield surrounding the glass with an illuminator behind it, so that only a small strip of the glass is exposed. The guard is designed to support the glass to prevent breakage but to allow access to nuts and permit easy reading. There was also shown a new method for making the water in the glass show red.

Simplex type MGO water meter was shown by Simplex Valve & Meter Co. in two new types, one with a floor stand mounting and one with a wall bracket mounting. The cylinder is now of seamless steel tubing for 2000 lb. pressure and there is a vernier on the integrator for use in weighed water tests.

Tag-Heppenstall moisture tester for lumber was a new product shown by C. J. Tagliabue Mfg. Co. By pushing a handle bearing contacts into a plank, an instantaneous moisture determination is made electrically. Here also was a new automatic temperature controller that indicates as well as controls.

Piping and Valves

Cast electric steel valves, made for 1350 lb. pressure to the A.S.T.M. standards were featured by Wm. Powell Co.

Edward Valve & Mfg. Co. showed a 10-in., 1350-lb. cast-steel, globe non-return valve, with Limitorque control mechanism, intended for the South Amboy Station of the Jersey Central Power & Light Co. Sectioned model of a 2½-in. angle non-return valve showed the double combination radial and end thrust ball bearings and other internal parts.

While the Walworth Co. featured its Sigma Steel valves and fittings, it announced a new product, chrome-nickel-iron pipe. This is especially adapted for use with chemicals or where corrosive or erosive actions occur. It is supplied with ends threaded, grooved for Victaulic coupling or beveled for welding. It is made in sizes from 1½ to 6 in. in 5-ft. lengths and designed to withstand hydraulic pressure up to 3000 lb. Fittings can be supplied of the same material.

Chromium-plated pipe saver, for use under conditions that might produce electrolysis, was shown as a new product by Pipe-Saver Corp. of America.

Pittsburgh Piping & Equipment Co. showed examples of its new creased bend, designed to permit a smaller bend and to decrease heat losses. Creases are formed on the inside of the bend; it is designed so that full thickness of metal is maintained on both inside and outside of bend.

Portable power pipe threading machine No. 999 was shown by The Toledo Pipe Threading Machine Co. This is designed for cutting and threading ½ to 2-in. pipe. It has safety friction gear, built-in oil pump, cutter head with 4 blades, ½-hp. universal ball-bearing motor and other features. There was also shown a new flange facing tool, driven by the power drive.

Beaver grooving tools for use with Victaulic joints were shown by The Borden Co. These tools, for pipe ½-in. to 16-in. size, are designed to lock on the pipe by means of an internal chuck so that the cutting knives cut a circular groove regardless of irregularities in the pipe. The tools are supplied for hand and power operation.

Examples of welded pipe lines in central stations and industrial power plants were shown by R. H. Baker Co., Inc.

Henry Vogt Machine Co. displayed drop-forged steel globe, gate and horizontal check valves up to 4-in. for 1350 lb., with solid body and bonnet.

Barco Mfg. Co. showed new designs of lubricated plug valves in which lubricant forced through the stem passes down through grooves on the side of the plug in such a way that every time the valve is turned, lubricant is forced between plug and seat.

Globack joints of various types, as previously described in Power Plant Engineering, were shown by Midwest Piping & Supply Co. and its Ballwood division. A new feature was a sample of a Van Stone joint on 85-per cent brass pipe.

Fire line valves of new design were featured by Jenkins Bros. built to meet class A and B requirements for such valves in New York and elsewhere. They have renewable discs and bronze bodies.

New valve-operating mechanisms of its own make were shown on 1500-lb. valves by Crane Co. These included electric, air and hydraulic motors.

Lunkenheimer Co. showed a new design of 6-in., 1350-lb. cast-steel, O. S. & Y. globe valves with bypass and geared handwheel.

M. W. Kellogg Co. showed a 30-in. by 1½-in. thick, 600-lb. forge-and-hammer-welded header for the Shuf-

fleton station, also a piece cut from the end of a 72-in. I.D. by 2-in. thick by 10 ft. 6-in. seamless drum.

Forged steel, toggle-top, 6-in. boiler feed valve for 2000 lb. pressure, built for the new 1800-lb. plant of The Philip Carey Co., was displayed by Schutte & Koerting Co. Herringbone gear pumps of 270 g.p.m. at 50 lb. pressure and specimens of 6-in. Radiafin tubes were other new products.

Parker Appliance Co. showed many ingenious applications of Parker tube couplings. One was a manifold for connection of compressed air lines to a number of draft gages so that the gage lines can be blown out without disconnecting them. Another was a device for sampling boiler feedwater. Valves and fittings for Diesel engines, tested to 7500 lb., were also shown.

Fantz-type return bends were shown by Stockham Pipe & Fittings Co. These are designed primarily for oil refinery service and consist of bends that can be clamped over special tube ends. They are designed to reduce friction and to permit changing tubes without disturbing others in the bank.

VALVES AND FITTINGS FOR PRESSURES UP TO 1350 LB., EXPANSION JOINTS, TUBE COUPLINGS AND SIMILAR EQUIPMENT REFLECTED MODERN TRENDS

Tube Turns, Inc., showed how its pipe bends and fittings of all sizes and degrees are designed to be welded into pipe lines. These fittings are supplied all scarfed ready for welding, are designed to maintain full wall thickness and to give greater speed and economy in erection.

L. J. Wing Mfg. Co. had a new small, compressed-air, turbine-driven blower for mine ventilation and similar applications. It has aluminum blades, bronze

fittings and roller bearings. It also has handles so that it can be carried about as needed.

Ventura-fin unit heater, in sizes from 125–200 sq. ft. equivalent radiation and 450–900 c.f.m., was shown by American Blower Corp., together with the Sirocco unit heater as described in the February 15 issue of Power Plant Engineering.

On its Thermolier unit heaters, Grinnell Co., Inc., called attention to new velocity nozzles and louvre constructions to direct heat to the floor when the heaters are hung high. Aluminum and chromium-plated casings were also shown for these heaters. Sample of new 1350-lb. Triple XXX piping with Sarlun joint was exhibited, also new forged steel I-beam clamps for beams up to 22 in.

On the Webster Modulator system, shown by Warren Webster & Co., attention was called to changes in the roof thermostat. The air line arrangement has been changed, a new type of casing provided, a steel compensating tube used in the thermostatic element itself, which is of brass and steel, and a micrometer gage is provided to aid in observing and adjusting the opening of the valve.

PUMPS, CONTROL EQUIPMENT AND METERS FOR ALL TYPES OF POWER PLANT WORK

Model U-20 unit air filter, shown by Midwest Air Filters, Inc., is now made so that the cells snap in and out by pressure of the thumb on snap locks located at the handles. Air-tight contact is provided for at all points. The filter material and cell construction otherwise remain unchanged. This company also showed its vertical sinuous filter, in which the air is directed in a

curved path through the elements to cause dust to drop out of the air.

Automatic radiator valve, shown by Fulton Sylphon Co. consists of a sylphon bellows, actuated by changes in room temperature, working directly on a special radiator steam valve, which is insulated so it will not be affected by the temperature changes.

Murray radiators, made of seamless copper tube with fins or extended surfaces welded to it, were shown by Murray Radiator Corp. These surfaces form flues, designed to promote heat transfer.

Steam Traps

Forged steel steam trap for 1800 lb. pressure was shown by Strong, Carlisle & Hammond Co. The body of the trap is pierced from a billet and the parts are of Anum-Metl. A blowoff valve for 1350-lb. service was also shown, its body machined from a billet. This is equipped with Anum-Metl seat and disc and is made in 1½, 2 and 2½-in. angle and straightaway types.

Forged steel trap designed for 1350-lb. steam pressure was displayed by Armstrong Machine Works.

Cochrane discharger for 1350-lb. pressure service was a new product shown by Cochrane Corp. This has a seamless, forged steel body and operates by action of solid displacement bodies on the ends of a pivoted beam. The motion of these actuates a pilot valve that admits steam to an unbalanced disc main valve, under control of a dashpot. At 300 lb. differential pressure this trap has a capacity of 200,000 lb. an hour.

Model FT-3 trap designed for handling large volumes of condensate at pressures up to 125 lb. as in paper machines and dry kilns, was shown by Sarco Co., Inc. This is a float-operated trap, with a thermostatic element for discharging air. The valve plunger is double-ported. The new Sarco air eliminator for heating systems was also shown. In this trap, a check valve prevents air being drawn in but allows it to vent from the system and a float rises against the valve to prevent escape of water.

Illinois Engineering Co. showed the boiler room hook-up of its original dual trap on vapor-vacuum heating systems.

Pumping Equipment

New products of Nash Engineering Co. were the Jennings suction sewage pump and the Jennings centrifugal pump. The latter is designed for motor drive, pump and motor being a compact assembly on the same base. Pump impeller is mounted directly on the motor shaft; the heavy motor bearings support the pump casing, with no flexible couplings. The sewage pump, in sizes from 45 to 450 g.p.m., is also a single unit, with a self-priming pump on the end of the motor shaft. A vacuum rotor exhausts the suction pipe first, then the pump impeller takes the liquid or sewage. A float controlled valve unloads the vacuum pump and it is sealed by water. It also removes gas and air from the entering liquid.

Pump for abrasive solutions, such as ash-laden water, was shown by Allen-Sherman-Hoff Co. This is a vertical, motor-driven pump to go in the ash sump. It has anti-friction thrust bearing, rubber guide bearings, agitator on suction and is designed so that only the surfaces of impeller blades, inside of shrouds and main volute chamber are touched by ash-laden water. A series of disks was shown that had been tested in ash-water, showing that chrome molybdenum nickel was worn the least, hence it was adopted for these pumps and similar applications. An ejector for pumping ash-water hydraulically was also shown.

New pumps for chemical plant work, a 4-in. single-stage unit and a 12-in. single-stage unit, were shown by Manistee Iron Works Co.

New self-priming centrifugal pumps, mounted with motors and engines on trucks or carriages and designed especially for construction work, were shown by The La Bour Co.

Radojet duplex two-stage air pump with horizontal inter and after condenser was displayed by C. H. Wheeler Mfg. Co. Condenser sections showed new designs for improving flow of vapor and steam, deaerating hotwell, baffles and provisions for maintaining condensate temperature the same as incoming steam temperature.

Lubrication

Lubricator for pulverizers was shown by The Texas Co. in conjunction with its exhibit of lubricants for general power plant use. This lubricator is designed to be placed in one of the arms of certain types of pulverizing mills, replacing the regular lubricant reservoir. As it rotates, centrifugal force causes the lubricant to flow out through a groove, calibrated so that the viscosity of the oil controls the amount of lubricant fed to the bearing.

Joseph Dixon Crucible Co. showed a machine developed in its laboratories for testing lubricant under actual operating conditions with loads up to 1840 lb. per sq. in. This is designed to give readings of speeds, temperatures and other factors needed to determine the effectiveness of lubrication.

Standard Oil Co. had a display of its lubricants backed by a miniature oil refinery to show the general arrangement of manufacturing processes. Turex, a new Diesel oil, designed especially for non-carbon forming properties, was shown, also Cylbrex for steam cylinders. These are designed to have a high affinity for metallic surfaces, to increase lubrication effect and to give greater economy.

The Keystone Lubricating Co. had a working display of the Pneuma-Lectric lubricating system, as described in the December 1 issue of Power Plant Engineering.

Regulating and Controlling Equipment

The Fisher Governor Co. displayed its new master controller, designed to be pilot controlled, sensitive and easily adjusted. It also announced an agreement with The Limitorque Corp. for exclusive use of the Limitorque electric valve-control mechanism with Fisher equipment for controlling pressure, liquid levels, flow and vacua.

Liquid level controller of new design was shown by Mason Regulator Co. A float, actuated by the rise or fall of liquid level in a chamber of the device, works a bell crank, with suitable glands and ball thrust bearing on the bell crank shaft to prevent leaks. This motion can be used to operate various types of balanced valves. Also, there was shown a No. 368 bellows type reducing valve, similar to former types but using a bellows instead of a diaphragm.

Curtis type T return trap and the packless pump

regulator, as previously described in Power Plant Engineering, were shown by Julian d'Este Co. A new temperature regulator for 0-300 deg. work was shown. In this device, a thermostatic liquid, in an element immersed in the fluid to be controlled, acts through a tube on the regulator bellows diaphragm, which in turn opens or closes the valve the right amount.

Foster Engineering Co., as its newest feature, displayed a 1400-lb., excess-pressure, pump governor built for the Holland station. This governor is of forged steel with chrome trim. It has a vent between water and steam pistons to show whether there is any leakage past the rings and has a guided spindle.

Latest type of feedwater regulator, in combination with the SLP variable excess pressure regulator, was shown by The Swartwout Co.

LUBRICANTS, MECHANICAL TRANSMISSION DEVICES, PACKING, SPRAY EQUIPMENT AND GASOLINE ENGINES

Other Mechanical Equipment

Allis-Chalmers Mfg. Co. showed a new Texrope drive unit consisting of a countershaft driven by Texrope drive from a motor, on one base to permit movement of motor or countershaft bracket and to allow the pulley on the other end of the countershaft to drive back towards and beyond the motor, if desired, with another Texrope drive. The new ARZ motor was also shown running in a box of dust, with the inside illuminated to show absence of dust on the windings. This is a fan-ventilated motor, fan on motor shaft, with air ducts around windings and grease-packed anti-friction bearings. It is designed for use in the presence of dirt, fumes and liquids.

Actenized Sumet Bronze was announced by a test demonstration of four bearings at the booth of Sumet Corp. A shaft mounted on four bearings of the new metal, was operated at 1725 r.p.m. One bearing was kept at 500 deg. F. with a blow torch, one was dry, one ran in water and a steam jet blew the lubricant out of the other. The test was to show how all the bearings operated continuously under these conditions.

Andale Co.'s Rotrex strainer was exhibited, consisting of a rotating straining wheel, driven from a

motor and reduction gear by gear teeth on its periphery, rotating in a casing. Spokes in the wheel divide it in sections. As each section passes, a stream of the water to be cleaned passes through the lower part of the casing and deposits refuse in the wheel which carries it to the top of the casing where another water stream washes it away. This device is particularly applicable to removing leaves, grass, etc., from large volumes beyond the capacity of other types of strainers.

The Sharples Specialty Co. displayed new horizontal centrifuge for chemical work. This consists of a strainer basket rotating horizontally at 1800 r.p.m., the material to be cleaned being forced through it by centrifugal force. The basket is cleaned by a knife with the machine at full speed.

Dodge Timken pillow blocks for 6 and 7-in. shafts, incorporating Timken roller bearings and of non-expansion and sliding sleeve types, were shown by Dodge Mfg. Co.

Link-Belt Co. showed the new herringbone speed reducer in operation, designed for ratios up to 300 to 1 and employing the Sykes tooth form. It is furnished in single, double and triple reduction types, with Timken roller bearings and heat treated alloy steel pinions integral with shaft. The chain drive variable speed reducer was also featured.

Morse Chain Co., by means of a neon stroboscope, showed the rocking action and link engagement of its joint. It also displayed a new ring oiler for chain drives, designed to eliminate the need for running the chain in an oil bath. A ring picks up clean oil from the top of a small pool of oil in the bottom of the casing and a wiper takes this oil off the ring, which runs on the shaft. From the wiper a pipe leads the oil to the chain. A modification of this is the disk oiler. A new flexible coupling, as described in the February 15 issue of Power Plant Engineering, and the chain speed reducer with roller bearings were also shown.

Garlock 430-Chevron Packing, designed to adjust itself automatically, was displayed by The Garlock Packing Co. It is designed to permit a large number of rings in shallow stuffing boxes and to pack tighter as the pressure increases. While originally intended for accumulators, presses, pumps and other hydraulic uses, data were presented showing its success with steam and other general applications.

Crane Packing Co. showed metallic universal oil pan gasket strip, designed in 25-ft. lengths for any shape flange or tank, to give double sealing effect and to be unaffected by oil or water, steam or acid. New manhole gaskets, armored with aluminum or copper were also shown, designed for any pressure. Metallic packing with asbestos core was shown in spiral form for high speed, high-pressure, hot oil pumps.

Refractories and Insulating Materials

Dearborn Chemical Co. featured its new No-Ox-Id-Ized asbestos felt wrapper for pipe lines. This is impregnated before coating with No-Ox-Id to water proof it and is then given a second coat to make a bond with No-Ox-Id on the pipe.

Johns-Manville Corp. showed insulation for ranges from —400 to 3000 deg. F. and presented data on new applications of Type A asphalt tile flooring in power plants.

New type of suspended arch with veneer of carborundum blocks over the refractory blocks was displayed by Carborundum Co.

Stic-tite insulating cement for insulating boiler walls, pipe and fittings for temperatures up to 1400 deg. was shown by Refractory & Engineering Corp. Packinsul for packing in as filler insulation was another new product of this company.

Spray painting equipment for all types of industrial and power plant work was a new product shown by Binks Mfg. Co. This consists of air compressor supplying not less than 7 c.f.m. per gun, a material container, regulating valves, hose and gun with a "strait-port" air nozzle.

Quigley Furnace Specialties Co. showed a new Series 100 of Triple A protective coatings. Besides being designed to resist acid, they are intended to resist oil, grease, alcohol, gasoline, etc. They are colored and are adaptable for painting machinery or pipe lines.

Great variety of synchronous motors and their controls, from 20-hp. up, was displayed by General Electric Co. Industrial controls and complete oil-immersed switching unit, including busbars, cable connectors and current transformers, was shown. A complete display of the synchronous selector supervisory system for the new municipal subways of the Board of Transportation, New York, attracted much attention. This showed how machines could be remote operated from control rooms and meter readings and operating information obtained from distant points.

Motor-driven valve operating units, for valves up to 6 in. were shown by Cutler-Hammer, Inc. as described in the February 1 issue. In addition a new 2-hp. across-the-line d.c. starter was shown. This is for 115 or 230 v., has thermal overload protection, push button on cover and is in a box the same size as the a.c. starters. Three-wire receptacles and caps with grounding blades for 10, 20 and 30 amp. were also shown, with other new fittings.

Sterling Engine Co. exhibited three gasoline engines, including one of the large Viking II 8-cylinder engines. With 8-in. bore, 9-in. stroke, 565 hp. is delivered at 1200 r.p.m. This is a duplicate of the engine being installed on the Pennsylvania Lehigh Bridge of Newark Bay.

Edwin Burhorn Co. showed a new trough distributor on its cooling tower. This is a rectangular trough across the entire width of the tower, with spray nozzles in the sides of the trough to discharge the water uniformly.

Engines running condensing can be set for non-densing operation or vice versa by simply changing the valve setting to take care of the changed compression and admission.

In changing from condensing to noncondensing operation much less compression will be needed, because the back pressure is greatly increased. Adjusting compression will automatically take care of the release on either a single or double eccentric engine.

It must be remembered that an engine can only carry about half as heavy a load when running non-condensing. If the engine was not fully loaded when operating condensing, however, it may be possible to carry the same load noncondensing by giving a longer cutoff. This will be taken care of by the governor up to the point of maximum cutoff.

A.S.M.E. to Celebrate 50th Anniversary in April, 1930

ON APRIL 5, 7, 8 and 9, 1930, many of the world's outstanding engineers will meet in New York, Hoboken and Washington to celebrate the 50th anniversary of the founding of the American Society of Mechanical Engineers. The exercises will be non-technical in nature and will stress the humanistic side of engineering. They will be preëminently an exchange of greetings between nations through the medium of a series of papers presented by a prominent engineer from each of 16 countries or geographical divisions of the world. These papers will develop the theme of what engineering has done for each author's country in a national sense and also for the advancement of world culture and civilization. These engineers will also endeavor to forecast the lines along which engineering may be expected to develop in the future and to inform the convocation of some of the great engineering problems confronting their respective nations.

The program will be carried out in three parts. At New York, on April 5, the delegates will be conducted to the McGraw-Hill Co. and will be entertained in the offices of the American Machinist. This portion of the program will commemorate the preliminary meeting of organization of the A.S.M.E. held on February 16, 1880.

The second portion of the program will be held at Stevens Institute, Hoboken, N. J., where the organization meeting of the society was held on April 7, 1880. With the idea of depicting the history of the society and of engineering during the past fifty years and the society's future, a pageant will be enacted. This pageant will feature the life history of an individual called "Control" and will utilize the most modern inventions of engineering in tracing this allegorical conception.

The third part of the program, the main sessions, in which each of 16 of the world's distinguished engineers will present a summary of his paper, will be held in Washington on April 7 and 8. Washington has been selected to accord with the national and international character of the celebration and the national and international scope of the society's future service to mankind.

Another outstanding function will be the Founders' Luncheon, also to take place in Washington on April 8. Following the luncheon, a session will be held in the U. S. Chamber of Commerce Building at which various awards will be formally bestowed. Honorary memberships will be awarded to individuals who have rendered conspicuous service to the society and the Holley, Melville, Gantt, A.S.M.E., Fiftieth Anniversary and other newly founded medals of distinction will be conferred.

At the dinner, also on Tuesday, April 8, the president of the A.S.M.E. will present a paper which will be the national report for the United States and will outline the future possibilities of service of the society. At this time, also, an eminent scientist will review the past contributions of science to engineering, the relation of engineering with respect to science, and the influence of science on the future of engineering. In addition, a prominent American will present, from an international viewpoint, an evaluation of the influence of engineering invention, development and accomplishments upon the cultural, social, economic and political progress of mankind and an outline of the future of engineering in solving the problems of mankind and in promoting international amity.

Other gatherings of interest include the reception at the White House for delegates and members of the society and their guests, and the A.S.M.E. president and officers' reception on the evening of the same day. There will also be trips about New York and Washington, during which the delegates, A.S.M.E. members and their guests will view the outstanding points of interest of those cities.

Fred R. Low Retires from Active Editorial Work

SERVICE, LONG and effective, to the power plant field has brought to Mr. Low the respect and high regard of all engaged in the industry. During his career he has seen the power plant grow from the small engine driving a single plant by belt transmission to individual industrial plants which, in size, overtop many central stations, and to the present super power plants, interconnected by great transmission systems.

At all times, in his work, Mr. Low has kept in step with this growth and the accompanying changes in plant operation, contributing by his thought and suggestions to aid advances.

In his retirement from active editorial work on Power, which takes place on January 1, he carries with him the best wishes of the hosts of friends he has made. May his well earned leisure be gladdened by the knowledge of the friendship and esteem in which he is held by power plant men in all branches of the industry.

News Notes

UNIVERSAL BEARING METALS CORP. of Rochester, N. Y., has purchased the processes, patents, patterns and goodwill of Bearium Bearings, Inc., and will supply the products of that company through the same operating and sales forces as heretofore. Officers of the Universal Co. are E. P. Langworthy, Buffalo, N. Y., president and treasurer; H. M. Rees, Boston, Mass., vice-president and secretary.

THE BOARD OF DIRECTORS of the Armstrong Electric and Mfg. Co., Huntington, W. Va., with executive offices at 522 Fifth Ave., New York, N. Y., announce the election of William L. Goodwin as president of the corporation. Mr. Goodwin has for many years been associated with the electrical industry. Starting in business in California 30 yr. ago, he developed the electrical jobbing business. His contributions to the industry, both as a business man and as a leader, drew national attention. Coming east under the sponsorship of the General Electric Co., Mr. Goodwin promoted a coöperative merchandising plan for the electrical business. Later he was elected operating vice-president of the Society for Electrical Development.

As president of the Armstrong Electric and Mfg. Co., Mr. Goodwin brings to his work not only a ripened experience but an enthusiasm for the electrical business, to which he has already made a unique contribution in coöperative business development.

FRED D. HOLDSWORTH, engineer in charge of air compressor design for the Sullivan Machinery Co. at its Claremont, New Hampshire plant from 1900 to 1928, died November 20. Mr. Holdsworth was born in Wales, Mass., October 23, 1867. He graduated from Worcester Polytechnic Institute in 1888 and, after experience as mechanical engineer with the Rhode Island Locomotive Works and with the G. F. Blake Co., afterwards Blake & Knowles, he joined the Sullivan staff in 1900, remaining at Claremont as mechanical engineer in charge of air compressor design until his retirement, about a year ago. He was awarded nearly 50 patents, development of the Sullivan angle-compound air compressor, portable gasoline engine driven air compressor, and electric motor-driven mine car air compressor, having taken place under his direction.

Mr. Holdsworth was a member of the American Society of Mechanical engineers, and had been secretary of the Green Mountain Branch. He was active in civic affairs, serving on the Claremont school board and in other positions. Mrs. Holdsworth, a son, and a married daughter survive him.

SHORT-CIRCUIT in the Riverside plant of the United Light & Power Co. at Bettendorf, Iowa, the evening of December 5, caused $4000 damage, wrecking two 13,200-v. transformers and disabling the station for nearly half an hour. Emergency generators in the Moline station, across the river, restored service in the community after a few minutes' delay. The short developed on the bus-bar structure of the plant when the two units were developing 23,000 kw. Seven new boilers were hastily steamed in the Moline plant, which then took over the entire load, furnishing power for the cities and high lines beyond.

MECHANICAL ENGINEERS have been giving careful study to the coal-handling problem at the Hudson Avenue station in Brooklyn, where increased efficiency is necessary to keep pace with the rapidly increasing capacity of the station as new units are added. Most of the coal arrives from Norfolk, Virginia, by ocean steamers carrying 4000 t. each, whereas formerly it arrived by lighter from Port Reading in 900 to 1200-t. shipments. It was found necessary to add a 100-ft. extension to the present west end trestle, in order to match the length of the boats so that towers may unload from any part of the hold. When completed, this extension will be equipped with rails and hatches for the towers and with a track system for dump cars. Two electrically-operated towers may thus unload continuously from any part of the trestle without moving the ship. A cab will be located on the outshore side of each tower from which a single operator can control the 3-t. bucket as well as the movement of the tower. The coal car equipment consists of a complete automatic electric railroad system with 12 cars, self operated or by motormen. When the coal trestle extension is completed, it will be possible to unload a large steamer at the rate of 500 t. an hour.

EXTENDING FROM THE Hell Gate generating station of the United Co. in the Bronx to the Dunwoodie distributing station of the Yonkers Co., a 132,000-v. cable will give Yonkers and portions of Westchester County about 125,000 hp. additional of electrical energy. This new line, which was placed in service during November, is some 12 mi. in length and resembles in design its counterpart that has been in operation some 2 yr. without a break in service. Both cables have hollow cores filled their entire length with oil under constant pressure. When the first of these cables was installed in 1927, it doubled, at one step, the highest operating voltage attained up to that time for underground cables. The new line not only increases the capacity for service to Westchester County but also makes it possible to draw power from Brooklyn and Manhattan, in case such need should ever arise.

COMPLETION of an electric transmission line between Metchun and Trenton switching stations makes possible a new power exchange between the Philadelphia Electric Co.'s stations including Conowingo and New Jersey plants at Kearny, Essex, Marion and Perth Amboy.

Transmission lines run parallel to the Public Service trolley line operating between Bayway and Trenton, conditions making it necessary to erect 295 towers of an average height of 118 ft. Tower foundations were sunk in swampy ground, in many cases, full of quick sand. For tower No. 45, for instance, it took a large force of men and 18 pumps no less than 30 days to sink the one foundation. Some towers reached 208 ft. at the Raritan River crossing at New Brunswick, the average tower weight being 14½ t. Some 232 mi. of aluminum wire were strung, with no serious accidents to anyone employed.

INDUSTRIAL EQUIPMENT EXPOSITION, featuring five classifications, materials handling, plant construction, power transmission, production control and factory operation will be held in the Stevens Hotel, Chicago, March 3 to 7, 1930. National Safety Association and American Society of Mechanical Engineers will have educational exhibits with chart and data covering their work. Manufacturers will demonstrate their product in the above classifications and the National Management Congress will have, March 3 to 5, a meeting with Society of Industrial Engineers, American Society of Mechanical Engineers, American Management Association, National Association of Cost Accountants coöperating. Eight sessions will be held for discussion of waste elimination, distribution, plant maintenance, wage plans, management and production control.

CONTINUANCE of the profit sharing plan for Brooklyn Edison Co. employes for the current year has been announced by Mathew S. Sloan, president of the New York Edison Co. and associated companies. The distribution is according to length of service and is made from the profits of the company. A pension fund is also maintained to which the company's employes contributed. Mr. Sloan states his belief that these two plans and the employes' investment fund have helped materially in increasing the length of service in the organization as the number who have been with the company five years or more has shown a large increase in 1929.

DEARBORN CHEMICAL Co. celebrated the opening of its new laboratories at 1029 West 35th St., Chicago, Ill., by a reception and dinner at the plant on the evening of Monday, December 16, attended by a large number of power plant engineers. Receptions were also held on December 16 and 17 to accommodate the large number of engineers who desired to inspect the new facilities.

After the dinner, which was served by the laboratory staff, speeches were delivered by George R. Carr, vice-president and general manager of the company; W. A. Converse, secretary; J. W. Brashears, director of purchases and manufacturing and by several of the guests. D. K. French, chemical director, conducted the guests through the new laboratories.

For the fourth time in 20 yr., the company has found it necessary to expand its laboratories devoted to water analysis and development of water treatments. The new laboratories occupy the entire second floor of Building No. 2. A main laboratory 50 ft. by 100 ft. contains equipment for water analysis. Eight smaller rooms are equipped for coal analysis, oil testing, factory control work, bacteriological examinations and special research. One of the features of the laboratory is the complete and well-indexed library.

Books and Catalogs

POPULAR RESEARCH NARRATIVES—Volume III, 174 pages, size 5 by 7 in., cloth, published by the Engineering Foundation, 29 West 39th St., New York; price, $1.00.

Many interesting stories are connected with the inventions, discoveries and researches which have given us the telephone, radio, electric light and power, automobile and aircraft and many other modern achievements. As the scientists advance and as engineers and chemists make new knowledge useful, their successes and failures become material for new stories. But scientists and engineers who have time and skill for writing stories in language which most of us can enjoy are rare birds.

Research Narratives are collected from researchers and inventors who are making life richer and pleasanter. They are put into layman's language very briefly in order that thousands of persons may enjoy the stories, get useful information and know a little more about the ways in which scientists and engineers are serving their fellow men. These little books, of which this is the third, should be of interest to everybody interested in the science.

FORTY YEARS WITH GENERAL ELECTRIC by John T. Broderick; first edition, 218 pages, size 5 by 7½ in., cloth, $2.50; Fort Orange Press, Albany, N. Y.

"Forty Years with General Electric" is a human interest story of one of America's great corporations written in the first person by a man who has seen from the firing line, as it were, the things of which he writes. With the descriptions which he gives of the spirit and growth of the General Electric Co. are vivid sketches of Thomson, Coffin, Steinmetz and other leaders of the electrical industry.

Several chapters dealing with Steinmetz presents material heretofore unpublished concerning the life and work of the late scientist. Some of the epochal achievements of research are also described.

TEST OF BOILER No. 4 in New York Edison Co.'s East River Station by W. H. Lawrence is the title of a reprint issued by the Combustion Engineering Corp., 200 Madison Ave., New York, N. Y. This is a 1500-hp. boiler equipped with water-cooled furnace and air preheater, fired with pulverized fuel, showing output of 532 per cent of rating for 72 hr.

VIBRATOR SCREENS for separation of aggregates are described in a 4-color, 16-page catalog issued by Stephens-Adamson Mfg. Co., Aurora, Ill. Illustrations, technical information and dimensions are included.

HIGH PRESSURE STEAM in the Paper Industry, a paper presented by J. B. Crane before a joint meeting of the News Print Service Bureau and the Northwestern Division of the Superintendents Association at Marinette, Wis., is issued in reprint form and copies are available upon request to Combustion Engineering Corp., 200 Madison Ave., New York City. Principles discussed apply to other industries where steam is used for power and process work.

AMONG THE EXPERIMENTAL METHODS used in determining stresses in structural and machine members due to external loads is the so-called brittle-material method. From a brittle material that has nearly a straight stress-strain diagram up to the ultimate strength of the material, a model is made of the member of more

or less irregular shape in which the stress is to be found; from the same material is also made a specimen of simple shape in which the stress due to a given load can be computed satisfactorily. The specimen of simple shape and the model of complex shape are then tested to destruction. The test of the simple shape gives approximately the ultimate strength of the material and the test of the model gives, with a fair degree of accuracy, the load which produced this ultimate stress in the most stressed fiber of the model; from these values the relation between load and maximum stress is obtained. Results of these tests are reported in Bulletin No. 195 of the Engineering Experiment Station of the University of Illinois, copies of which may be obtained without charge from the Engineering Experiment Station, Urbana, Ill.

INTERNAL COMBUSTION ENGINES, third edition, by Robert L. Streeter and Lester Clyde Lichty; 445 pages, 275 illustrations, 43 tables; cloth, 6 by 9 in.; published by McGraw-Hill Book Co., New York, N. Y., 1929. Price $4.00.

In this revision, the authors have discarded much descriptive matter and have substituted much fuller treatment of underlying principles as they are now understood, in the various subjects discussed, in some cases going beyond what may be desired for undergraduate study. The book contains, therefore, much material that is useful for reference.

Besides treatment of the thermodynamic principles, the authors have devoted much space to design of parts, advanced thought on such subjects as engine vibration and balance being ably presented in a new chapter. Another new chapter deals with valves and valve mechanisms.

Although of particular use to the student and the designer, the book will be found useful also to the operator, particularly such chapters as that on engine lubrication, which has been added to this volume. The chapter on liquid fuels and detonation has been rewritten and brought up to date.

SELSYN OPERATED DEVICES for remote indication and record of liquid level, flow, pressure, temperature, draft, position and other factors, is the title of the 12-page bulletin, No. 110, issued recently by the Bailey Meter Co. of Cleveland. This catalog explains how the Selsyn motor, a device which is in use on the more modern battleships for directing and controlling gun fire, has been applied to the long distance transmission of various indications and records. Photographs, drawings and diagrams illustrate the principle of operation and the numerous applications in which this system of long distance transmission may be used. The application of the Selsyn motor to control systems is also explained.

OF INTEREST TO THOSE concerned with industrial applications are three new bulletins recently issued by the General Electric Co. One of these, GEA-1146, deals with electric furnaces; GEA-261A is entitled "Electric Heat in Industry" and describes the application of electric heat to group station operation commonly found in industrial plants; bulletin GEA-151B, which supersedes GEA-151A, is entitled "Motor Drives for Rolling Mills."

CHUSE SIX-CYLINDER vertical uniflow engines are described in detail in Bulletin No. 109 issued by Mattoon Engine Works, Mattoon, Ill., covering sizes, governing valves, reciprocating parts, bearings, frame and shaft.

NUWAY HORIZONTAL tubular boilers are described and illustrated in an attractive catalog, No. 400, issued by Nuway Boiler and Engineering Co., 333 N. Michigan Ave., Chicago, Ill. The novel method for guiding circulation and of providing a water-wall furnace are interestingly shown.

IN A 126-page book, well illustrated with tables and charts, the complete survey of industrial development in the United States and Canada has just been issued by the National Electric Light Association, 420 Lexington Ave., New York, N. Y. This is the coöperative survey made by the Civic Development Committee of the National Electric Light Association and the Policyholders' Service Bureau of the Metropolitan Life Insurance Co., to which attention has previously been called in these columns.

AUTOMATIC, GAS-FIRED high-pressure boilers are described and illustrated in bulletins issued recently by Steam and Combustion Co., 205 West Wacker Drive, Chicago, Ill.

PRODUCTS AND PUBLICATIONS of the subsidiary manufacturing companies of the United States Steel Corp., New York City, are listed and described in detail in a 50-page bulletin just issued by that corporation.

IN BOOKLET No. 1 just issued by Schutte & Koerting Co., Philadelphia, Pa., all the equipment this company builds for steam power plants is illustrated and described. This includes emergency trip and throttle, heavy duty steam and gate valves, valves for bleeder line protection, pressure reduction and exhaust steam, feedwater evaporators, heaters and injectors, desuperheaters, low level jet condensers, air, oil and water coolers, steam jet air pumps and other apparatus.

COLUMBIA GENERATORS for electroplating, electrotyping and electro chemical processes are discussed in a new bulletin by Columbia Electric Manufacturing Co., 1282 E. 53rd St., Cleveland, Ohio.

REPORT OF TESTS on 1350-lb. piping materials is given in a 12-page illustrated bulletin by the National Valve & Manufacturing Co., Pittsburgh, Pa. This bulletin shows the results of steam and hydraulic tests on piping materials recommended for this service by the recent tentative American standard.

FOXBORO INSTRUMENTS in the power plant are described and their applications illustrated in Bulletin No. 115-2, just published by the Foxboro Co., Foxboro, Mass. Details of the instruments are shown, such as flow meters, liquid level gages, thermometers, draft gages and so on, of indicating and recording types. A large cross section of a modern power plant shows applications of instruments in measuring the various quantities.

THE BLACK SERVANT, an automatic coal stoker of the screw conveyor type for small and medium size installations, is described in a bulletin issued by The Black Servant Manufacturing Co., St. Louis, Mo.

CHICAGO CENTRIFUGAL PUMPS of all types are described and illustrated in a 200-page book issued by Chicago Pump Co., 2336 Wolfram St., Chicago, Ill. This book is 8½ by 11 in. in size, and contains many engineering tables for use in design and selection of pumps. The catalog is marked with the A.I.A. standard classification for filing purposes, the sections dealing with horizontal, vertical and heating pumps being divided by index sheets.

IN AN ATTRACTIVE BULLETIN, the American Institute of Steel Construction, Inc., New York City, describes the Sixth Street Bridge over the Allegheny River at Pittsburgh, which was selected as the most beautiful steel bridge completed during 1928.

FIRST ISSUE of "Isolation," a publication devoted to the scientific, practical and economical application and study of material and methods of deadening and eliminating vibration and noise, has been sent out by the Korfund Co., Inc., 235 E. 42nd St., New York City. This publication will appear quarterly.

PROTECTIVE COATINGS for new boilers, is the subject of bulletins 1180 and 1181 recently issued by the Dampney Co. of America, Hyde Park, Boston, Mass. These describe methods used on about 50 new large-size water tube boiler installations, totaling over 200,000 hp., to free the water and steam surfaces from mill scale so that Apexior protective coatings can be easily applied to these boilers after they are erected in the field.

BUCKEYE DIESEL ENGINES, now being built in sizes up to 400 hp., are described and illustrated in detail in a 24-page bulletin issued by the Buckeye Machine Co., Lima, Ohio.

IN CATALOG 15, sectional cast-iron hoppers lined with high temperature refractories are described by Hahn Engineering Co., Division of Lancaster Iron Works, Inc., Lancaster, Pa.

MARION-TYPE U UNDERFEED STOKER, incorporating a screw feeder, blower and driving mechanism, for boilers up to 200-hp. rating, is described and illustrated in a bulletin just issued by Marion Machine Foundry & Supply Co., Marion, Ind.

MOTOR MAINTENANCE EQUIPMENT and electrical specialties are described in a 60-page bulletin by Ideal Commutator Dresser Co., Sycamore, Ill. This publication, B-29, is intended to be an encyclopedia on the subject, and contains discussion of the development of modern methods of commutator resurfacing, a special chapter on direct current generators, one giving details of commutator troubles and remedies and various engineering tables. Data on many different tools and machines in use today in industrial plants and power plants are given and the book is profusely illustrated.

PIPE WELDING with stock fittings in the process industries is discussed in bulletin No. 104 by Tube-Turns, Inc., Louisville, Ky. This describes fittings forged from seamless steel tubing and ready for welding into line and gives data on their design and application.

LINK-BELT Rotary Railroad Car Dumper is described in Book 1004 issued by Link-Belt Co., of Chicago. The Dumper is illustrated in action, also the main features of its mechanism. It is designed to bring the lifting type of dumper within the reach of those whose unloading requirements are small. The book will be sent upon request to anyone interested.

SURFACE AIR COOLERS as made by the General Electric Co. for cooling generators or other machines by a closed system of ventilation are illustrated in detail and described in Bulletin GEA-2264 of the company, Schenectady, N. Y.

Power Plant Construction News

Calif., San Francisco—The Pacific Gas & Electric Co., 245 Market Street, will proceed with superstructure for group of buildings for an equipment storage and distributing plant at Eighteenth Street and Shotwell Avenue, estimated to cost about $200,000.

Colo., Telluride—The Alta Mining Co., plans installation of electric power equipment in connection with proposed rebuilding of mill, recently destroyed by fire with loss reported at more than $250,000.

Conn., Hartford—The Southern New England Telephone Co., Hartford, has completed plans for a one-story boiler plant on Hicks Street, reported to cost close to $30,000 with equipment.

Conn., Middletown—Wilcox, Crittenden & Co., 3 South Main Street, plan construction of a boiler house in connection with extensions and improvements in hardware manufacturing plant. Lockwood, Greene Engineers, Inc., 24 Federal Street, Boston, Mass., is engineer.

Conn., New Haven—The New York, New Haven & Hartford Railroad Co., New Haven, plans construction of a power plant for shop service, including additional steam heating facilities to cost approximately $1,000,000, work to be carried out in connection with a 1930 expansion program.

Fla., West Palm Beach—The East Coast Refrigerating Co., West Palm Beach, is arranging for early acquisition of local site for new cold storage and refrigerating plant to cost approximately $85,000, with equipment.

Ga., Atlanta—The United States Cold Storage Co., care of A. Epstein, 2001 West Pershing Road, Chicago, Ill., engineer, has plans nearing completion for a multi-story cold storage and refrigerating plant at Wall and Pryor Streets, Atlanta, to cost more than $2,000,000, with machinery.

Ill., Salem—The Board of Local Improvement is having revised plans prepared for a filter plant at the municipal waterworks, reported to cost about $35,000. The Caldwell Engineering Co., 211 State Street, Jackson, Ill., is engineer.

Ill., Rockford—The Mechanical Universal Joint Co., Nineteenth Avenue, plans installation of electric power equipment in proposed three-story plant addition, reported to cost close to $100,000. Peterson & Johnson, Swedish-American Bank Building, Rockford, are architects.

Ind., Goshen—The Chase Bag Co. plans installation of electric power equipment in proposed one-story plant unit at Goshen, 120x330 ft., reported to cost about $100,000. Headquarters of company are at 250 West Fifty-seventh Street, New York.

Iowa, Cedar Rapids—The Iowa Railway & Light Corporation, Cedar Rapids, is said to have plans in progress for a hydroelectric power plant to cost in excess of $1,500,000, work to be placed under way during coming year.

Ky., Louisville—The Louisville Water Co., is said to be planning the installation of pumping equipment and auxiliary machinery in connection with an expansion and improvement program to cost more than $150,000.

La., New Orleans—The Chief Engineer, Inland Waterway Corporation, 320 Magazine Street, is asking bids until Jan. 15, for twin 1200-hp. triple expansion, vertical reciprocating marine steam engines, as per specifications on file.

La., Shreveport—The Beard Corporation, Shreveport, contemplates the installation of electric power equipment in connection with an expansion and improvement program at its welding plant, entire project to cost $200,000.

Me., Matawamkeag—The Northern Paper Co., East Millinocket, Me., plans construction of a power house at its mill near Matawamkeag, reported to cost more than $45,000.

Md., Baltimore—The F. G. Schenuit Rubber Co., 1200 Mount Royal Avenue, plans installation of electric power equipment in connection with proposed rebuilding of portion of plant at Clipper Road and Union Avenue, recently destroyed by fire with loss reported at close to $100,000.

Mass., Boston—The George Lawley & Sons Corporation, Ericson Street, Dorchester, plans installation of electric power equipment in connection with proposed rebuilding of joiner and woodworking shop at ship yard, recently destroyed by fire with loss reported at close to $100,000.

Mass., North Reading—The Department of Public Health, State House, Boston, is said to be planning extensions and improvements in power plant at North Reading to cost about $45,000.

Mich., Detroit—The United States Rubber Co., 6600 East Jefferson Street, will install electric power equipment in connection with an expansion and improvement program now in progress at local plant, reported to cost more than $250,000. Headquarters are at Broadway and Fifty-eighth Street, New York.

Minn., Cloquet—The Northwest Paper Co., Cloquet, plans installation of electric power equipment in connection with proposed mill addition to cost in excess of $100,000. The Jacobson Engineering Co., Plymouth Building, Minneapolis, Minn., is engineer.

Mo., St. Louis—The Union Electric Light & Power Co., Twelfth and Locust Streets, is said to be planning early expansion in Cahokia generating plant near St. Louis, to include the installation of a 100,000-hp. generator unit and auxiliary equipment, entire project to cost more than $1,000,000.

N. J., Camden—The Armstrong Cork Co. is said to be planning the installation of electric power equipment in new four-story and basement addition to plant to cost close to $100,000.

N. Y., Buffalo—The Stone Ice Cream Co., 1480 Hertel Avenue, plans installation of electric power equipment in proposed ice cream manufacturing plant on Jefferson Avenue, entire project to cost about $400,000; a boiler house is projected. Bacon & Lurkey, 997 Main Street, are architects.

N. D., Williston—The Montana-Dakota Power Co., Minneapolis, Minn., is considering the construction of a steam-operated electric power plant in the vicinity of Williston, reported to cost about $250,000, with equipment. It is proposed to begin work in the spring.

Ohio, Akron—The Palmer Match Co., is said to be planning the installation of electric power equipment in connection with new additions to plant, entire project reported to cost more than $75,000. John L. Walker is president.

Ohio, Cleveland—The American Steel & Wire Co., Rockefeller Building, plans installation of electric power equipment in connection with an expansion and improvement program at its local Newburgh works, entire project to cost close to $10,000,000.

Ohio, Cleveland—The Standard Oil Co. of Ohio, East Ohio Gas Building, plans installation of electric and steam power equipment in connection with a proposed 1930 expansion program at refineries and distributing plants, entire project to cost $2,750,000.

Ore., Salem—The Oregon-Washington Water Service Co., San Francisco, Calif., E. K. Barnum, chief engineer, is said to be planning the installation of a filtration plant at Salem, with capacity of 9,000,000 gal. per day, project to include a low-lift pumping station.

Pa., Lansdowne—The Lansdowne Heating Co., J. M. Delton, Drexel Hill Lumber & Supply Co., president, is considering the construction of a one-story steam power plant for central heating service, reported to cost close to $50,000, with system.

Tenn., Johnson City—The Tennessee Eastern Electric Co. is arranging an expansion and improvement program in 1930, including extensions in power facilities, transmission lines, etc. to cost approximately $100,000.

Wash., Tacoma—The Department of Public Utilities, Ira Davisson, commissioner, is considering the construction of an addition to municipal steam power plant on Dock Street, for auxiliary service, to develop a capacity of about 40,000 hp.

W. Va., Harpers Ferry—The Harpers Ferry Electric & Power Co., is said to be planning an expansion and improvement program in 1930 to cost more than $200,000, including additional power facilities, transmission and distributing lines.

Wis., Milwaukee—The Milwaukee Electric Railway, Light & Power Co., Third and Michigan Streets, has plans maturing for an addition to local power plant, reported to cost more than $3,000,000, with equipment; watertube boilers and other steam power equipment will be installed.